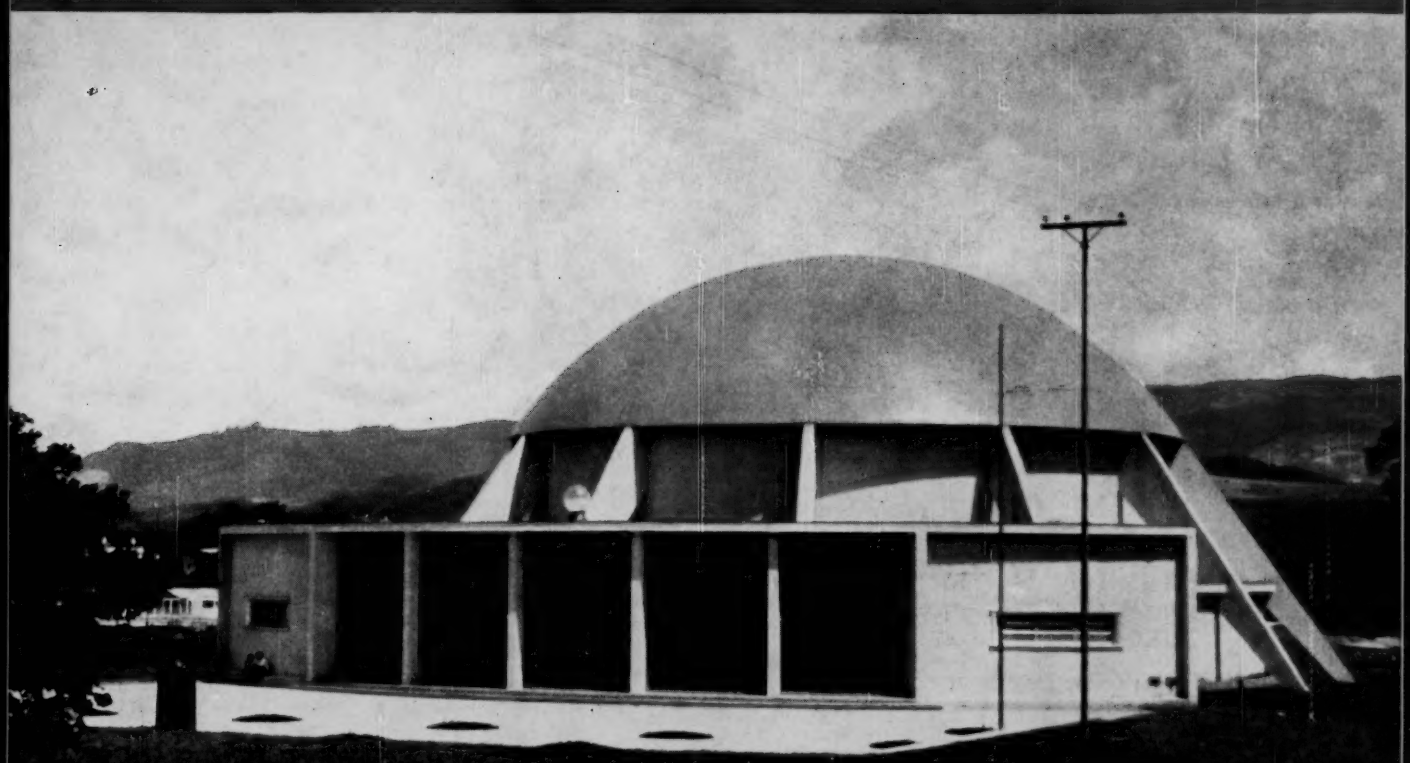
TELESCOPE



Planetarium in Venezuela

Explosions in the Nuclei of Galaxies

Astronomy in Venezuela

Astronomical Results from [illegible]

IAU Symposium on Galaxies

Measuring Double Stars with a Filar Micrometer

Occultation Supplement

1962 Predictions

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Questar's base casting is made by the Boose Aluminum Foundry of Reamstown, Pennsylvania. The alloy used is Alcoa No. 356 tempered to the T-6 condition. Because it contains 7% silicon it is exceptionally free-flowing in the molten state. It has the virtue of great resistance to the acids of perspiration or the corrosive salts of sea water, and retains its polish very well. We use the piece, therefore, without paint or surface treatment. If scratched or nicked, one may always polish out the defect and renew the surface luster. The workmen at Boose pour these castings one at a time into moulds prepared from metal matchplates instead of wooden patterns.

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QUESTAR

NEW HOPE, PENNSYLVANIA

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*

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Vol. XXII, No. 5 NOVEMBER, 1961

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COVER: This recently completed building is the home of the world's latest major planetarium installation, in Caracas, the capital city of Venezuela. In charge of the new planetarium is Dr. Jose Abdala, director of Cagigal Observatory. Photograph by G. Eskildsen. (See page 251.)

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The First Two Decades

WITH this issue, SKY AND TELESCOPE marks its 20th birthday. Back in November, 1941, just over 6,000 subscribers received our red-covered first number. Its 28 pages told about Leonid meteors, Mars, an aurora of spectacular brilliance, and the latest findings regarding the distance from Earth to Sun.

Amateur news was an important part of that first issue. The Astronomical League was in the first stages of organization, and two pages were devoted to the plans for this now thriving federation of amateur societies. A full report was given of happenings at the American Association of Variable Star Observers' 30th annual meeting. That society has just passed its 50th anniversary.

Also in that number are celestial photographs, a full-sky star chart, notes for amateur telescope makers, and some news from abroad. There is the department still called Observer's Page, as well as Books and the Sky. In his Astronomical Anecdotes, Roy K. Marshall discusses record years for comets.

Evidently, this magazine has maintained a distinctive identity over the years, with two overlapping purposes. One is to serve as a forum for amateur astronomers, exchanging their views and experiences and furnishing them with observing data.

The other is to bring to a broader public of scientists and educated laymen detailed and reliable information concerning new astronomical advances. Radio astronomy and artificial satellites are two major fields whose growth has been reported in SKY AND TELESCOPE from their primitive beginnings. Today the importance of staying well informed about the heavens is greater than ever.

In a sense, this magazine is older than 20 years, because it was formed by combining two earlier periodicals: the *Sky*, published since 1936 at the Hayden Planetarium in New York City, and the *Telescope*, a popular quarterly started at Perkins Observatory in 1931. It was continued in 1934 at Harvard Observatory, being bi-monthly until 1941. With the encouragement of Harvard's director, Harlow Shapley, the two journals were merged under the present editor.

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Explosions in Nuclei of Galaxies

OTTO STRUVE, *National Radio Astronomy Observatory**

DURING the past few decades it has become abundantly clear that our galaxy is a radio source. Within the Milky Way, we are now able to distinguish several different types of emitting regions. First, there are large neutral-hydrogen clouds which can be detected at a wave length of 21 centimeters. This radiation, as predicted by H. C. van de Hulst, is caused by minute changes in the internal energies of hydrogen atoms.

Next, there are regions of ionized hydrogen which are known optically as emission nebulosities. These produce thermal radio radiation, as a consequence of free-free transitions of electrons traveling in hyperbolic orbits near positively charged ions. Also, certain discrete radio sources such as the Crab nebula, Cassiopeia A, and perhaps the Loop nebula in Cygnus and several more, are remnants of supernova explosions in different parts of the Milky Way.

Lastly, there is a weak background of continuous radiation that is strongest near the galactic plane. It may result from the superposition of many old supernova explosions, an interpretation discussed especially by R. D. Davies in England.

Some galaxies not very far from our own Milky Way system are known to be radio sources. Many of the more distant galaxies emit enormous continuous radio fluxes with spectral characteristics quite similar to those of supernova remnants in the Milky Way. This radiation becomes stronger with increasing wave length, unlike the so-called thermal radiation which slowly weakens as the wave length increases. Because of this similarity between strong radio galaxies and Milky Way supernova remnants, several astronomers have suggested that in some way the emission of radio galaxies is also produced by supernovae.

There have been two main difficulties in this interpretation. Why, in a cluster of galaxies such as the one in Virgo, should the two elliptical systems M87 and M84 be strong radio sources, while other ellipticals of about the same size and mass are not? The second difficulty has been stressed by G. R. Burbidge of Yerkes and McDonald Observatories. According to him, supernovae exploding at the expected rate of one in several hundred years cannot supply as much energy as is radiated by an intense radio galaxy, which may emit a million or even 10 million times more than an ordinary galaxy.

In the case of M87, the total energy of the radio source is approximately 10^{58} ergs. A single supernova releases only about 10^{50} or 10^{51} ergs. Hence, it would require 10^7 or 10^8 supernova explosions to produce the presently observed total energy of M87. If a supernova occurs in that system only once in 100 years, it would take several billion years to accumulate the 10^{58} ergs.

We do not know exactly how long the radio emission of a supernova remnant may last. The Crab nebula is about 900 years old and is very strong. The Loop nebula may be many tens of thousands of years old. Burbidge estimates that the radio emission from a single supernova explosion may continue some millions of years. Clearly, the observed rate of supernovae in the Milky Way or Andromeda system is far too low to build up the observed emission of a strong radio galaxy.

In exceptional cases, the discrepancy would be even more pronounced. As a result, astronomers have been looking for some process that might produce supernova outbursts much more often in some galaxies. As Gordon Stanley of California Institute of Technology recently remarked (at a discussion on radio astronomy at the National Radio Astronomy Observatory in May, 1961), what is really needed is a process involving the almost simultaneous explosion of many supernovae in one galaxy.

Burbidge's new ideas on this subject were presented, with other interpretations, at the Green Bank discussion and appeared in *Nature* for June 17th.

It has been known for some time that the central condensations of galaxies often contain large numbers of stars. At the center of the Andromeda galaxy is an almost starlike object, which has been studied by W. Baade and F. Zwicky with the 200-inch telescope. This nucleus is stated by Zwicky to be slightly elliptical, measuring about 1½ by 2½ seconds of arc.

More recent observations of M31's nucleus were made in 1959 with the Lick 120-inch reflector by A. Lallemand, M. Duchesne, and M. Walker. Their spectroscopic measurements demonstrate that the nucleus rotates with a velocity at its outer edge of about 90 kilometers per second, indicating a rotation period of roughly

The central portion of the great Andromeda galaxy M31 is recorded here by the 200-inch telescope, an 80-second exposure in blue light (Eastman IIa-O emulsion). On the original negative the nucleus appears as a small bright patch, about 1½ by 2½ seconds of arc. Note the dark absorption lanes. Mount Wilson and Palomar Observatories photograph.

*Operated by the Associated Universities, Inc., under contract with the National Science Foundation.

Two views of the Sombrero galaxy (Messier 104 in Virgo), a nearly edgewise spiral. Both photographs were taken by the 60-inch Mount Wilson reflector, one with a long exposure to bring out the spiral structure, the other with a short exposure to reveal the small, bright nuclear region. The long, dark lane is caused by obscuring material in the galaxy's equatorial plane. This and the two pictures at lower right are from Mount Wilson and Palomar Observatories.

500,000 years. The radius is about 7½ parsecs (25 light-years). From Kepler's third law, the Lick observers estimated that the density is some 1,700 solar masses per cubic parsec in the nucleus. Therefore, it is comparable in size to a globular cluster, but much more closely packed, containing possibly 10 million stars.

The nucleus of our own galaxy cannot be observed with optical instruments, because of intervening interstellar matter. In a recent paper in the Russian *Astronomical Journal*, V. I. Moroz reports that efforts to locate the galactic nucleus in infrared wave lengths of one to 2.5 microns have been unsuccessful. The observational technique could detect a surface brightness comparable to one 8.5-magnitude star per square minute of arc. However, in a paper submitted to the *Physikalische Blätter*, Zwicky has expressed the hope that nuclear radiation between one and 1,000 microns may prove detectable from rockets or stratospheric balloons.

The radio emission of the galactic center, known as Sagittarius A, has been observed many times at different wave lengths. The most thorough study was made by F. D. Drake at Green Bank, with the 85-foot Tatel radio telescope (SKY AND TELESCOPE, June, 1959, page 428). There is a strong double source, consisting of two unequal components very close to the galactic center as defined by radio observations. Drake believes that this double source is produced by thermal radio emission of ionized hydrogen gas, and he has explained its presence by the radiation of approximately one billion very old stars of Baade's Population II.

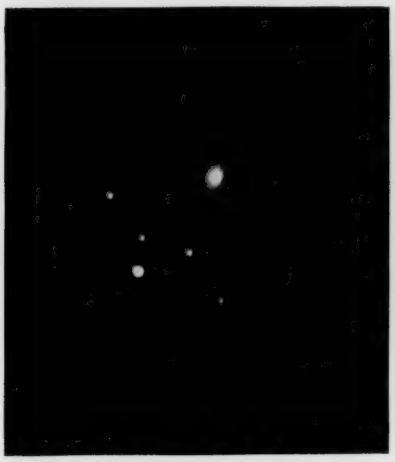
An independent confirmation of Drake's work was published by Y. N. Pariisky in the *Proceedings* of the Soviet Academy of Sciences, based on work with the large radio telescope at Pulkovo Observatory. He used wave lengths of 3.2 and 9.4 centimeters. There seems to be no doubt that the nucleus of our own system is a "super globular cluster," occupying a volume of several thousand cubic parsecs and containing a billion or more stars. The average density of this nucleus would roughly match that of the M31 nucleus.

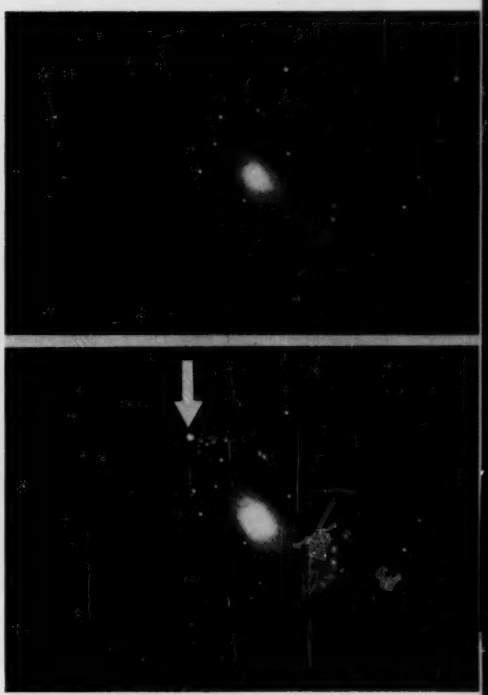
Neither our own nor the Andromeda galaxy is a strong source of radio emission. Supernovae have been observed in both, but they are not known to occur at an abnormal rate in the nuclei. We do not know how closely packed the stars are at the centers of galaxy nuclei. For that matter, we have no accurate knowledge of the central stellar densities of globular clusters, but they are enormous for the largest clusters, according to Mrs. Helen Sawyer Hogg. From the work of S. C. B. Gascoigne and E. J. Burr, she points out, "Whereas in the region of the Sun the light emission is equivalent to that from 0.0005 star of zero absolute magnitude per cubic parsec, the figure at the center of ω Centauri is 30000 times this, and at the center of 47 Tucanae a million times."

It is thus reasonable to believe, with Burbidge, that a cubic parsec at the center of the "super globular cluster" of a galaxy may contain as much mass as 10 million or more suns. The necessary resolution is not possible with direct observations. In the case of the Virgo cluster of galaxies, where there are many giant ellipticals as well as spirals, small ellipticals, and irregular galaxies, a nucleus with a diameter of one parsec would subtend only 1/100 second of arc, far less than can now be resolved on the best photographs. However, plates studied by Burbidge and his wife show that some large and massive ellipticals have a strong concentration of starlight at their centers — many times greater than is known for any globular cluster or for any of the nearby spirals.

The origin of such high-density nuclei, if they exist, need not concern us here. Perhaps they are formed in the same way as ordinary star clusters, or they may grow by capturing stars, as Zwicky has suggested.

If we adopt the hypothesis proposed by Burbidge, the innermost part of a large elliptical galaxy may have some remarkable properties. A star's nearest neighbors would be only a few hundred astronomi-





Left: Just above the brightest star in this picture is a supernova that flashed out in the Ursa Major galaxy NGC 2841 four years ago. The photograph was taken by S. van den Bergh with the Perkins Observatory 69-inch reflecting telescope.

Right: The arrow marks the supernova of 1940 in spiral galaxy NGC 4725. No trace of the new star appears in the upper photograph of the pair, taken in 1931. This galaxy is in the Ursa Major cluster.

cal units distant. Such a star presumably could not retain an extensive cloud of comets as the sun does; any comets formed would be ejected into intragalactic space. It is even doubtful whether stars in a galactic nucleus could retain planetary systems, because of the gravitational attraction exerted by other stars during close encounters. Collisions between stars would occur at a rate of approximately one per year. Burbidge pointed out that such stellar collisions might produce supernova outbursts, an idea recently discussed by I. S. Shklovsky.

Burbidge, however, is more interested in the possibility that once a supernova occurs, it could trigger a chain reaction of similar explosions among neighboring stars in a superdense galactic nucleus. The main part of his theory deals with the absorption by nearby stars of the energy released by a supernova explosion. This energy consists of gamma radiation, X-rays, and high- and low-energy charged particles. The gaseous shell of the exploding star expands at the rate of a few thousand kilometers per second, but charged particles, such as relativistic electrons and free protons, may travel much faster. The high-energy radiation is, of course, propelled in all directions with the velocity of light.

The Yerkes astronomer has computed the fraction of this energy that would strike a stellar neighbor. Much of it must be absorbed by the outer layers of the star, and Burbidge has calculated that these would be heated to temperatures as high as 10^9 degrees. Nuclear reactions would at once begin to operate in the regions hotter than 10^7 degrees. The present theory does not completely describe the manner in which the hot region will travel inside the star, but it could possibly produce a second supernova outburst, which, in turn, would cause similar explosions in other stars until virtually all the stars in the high-density nucleus had exploded. The entire catastrophe might take 150 years or even less.

According to Burbidge, "The first supernovae will brighten the galaxy in a normal fashion. . . . After a considerable amount of gas has been ejected, however, succeeding supernovae will irradiate this gas. It will become ionized and will achieve a temperature near 10,000°. It will also have a high random velocity since the gas is ejected from the supernovae at several thousand kilometres a second. In such a situation all the forbidden lines excited in nova shells will appear. Such a situation is reminiscent of what we see in some of the abnormal radio sources such as Cygnus A, 3C-295, NGC 1275, and NGC 1068. . . .

"In the first stage, the galaxy will apparently brighten in its nuclear region. In the second stage, very strong emission lines excited by electron collisions and high random velocities will appear. In the third stage, the random velocities of the gas will die down and eventually all the gas will disappear since it has velocities considerably in excess of the escape velocity of the galaxy."

The radio emission may not be observable for the first few years of these events, but it will gradually become stronger and should persist long after all optical evidence of the triggered explosions has disappeared.

The total number of stars outside the high-density nucleus is much greater than inside it, so a supernova is much more likely to appear in a low-density spiral arm or in the tenuous outer parts of an elliptical galaxy. It will then give rise to an object like the Crab nebula or Cassiopeia A, but neighboring stars are too far away to be strongly affected by such explosions. The supernova remnant will remain visible optically for many centuries, and will produce nonthermal radio emission for hundreds of thousands of years.

However, once in a long while a supernova may explode inside the high-density nucleus. We may then observe the operation of Burbidge's trigger mechanism until the entire nucleus has been blown up as a succession of supernovae. For such a process to occur, the galaxy must possess a nucleus of very high star density. It will then be a matter of chance whether a supernova first appears in the high-density nucleus or in the less dense outer portions of the galaxy.

These remote galaxies of diverse form were recorded with the 200-inch telescope. The brightest of this trio in Leo is NGC 3190 (lower center), a 12th-magnitude spiral that is probably similar to our own Milky Way system. Above and to the right is NGC 3187, a barred spiral, with two arms apparently originating from the ends of a central bar. At upper left is the elliptical galaxy NGC 3193. North is upward on this Mount Wilson and Palomar Observatories photograph.

Cagigal Observatory, situated on a hill in the middle of Caracas, is the Venezuelan center for astronomical and geophysical studies. Sites for a new observing station are now being surveyed. Photograph by the author.

Astronomy in Venezuela

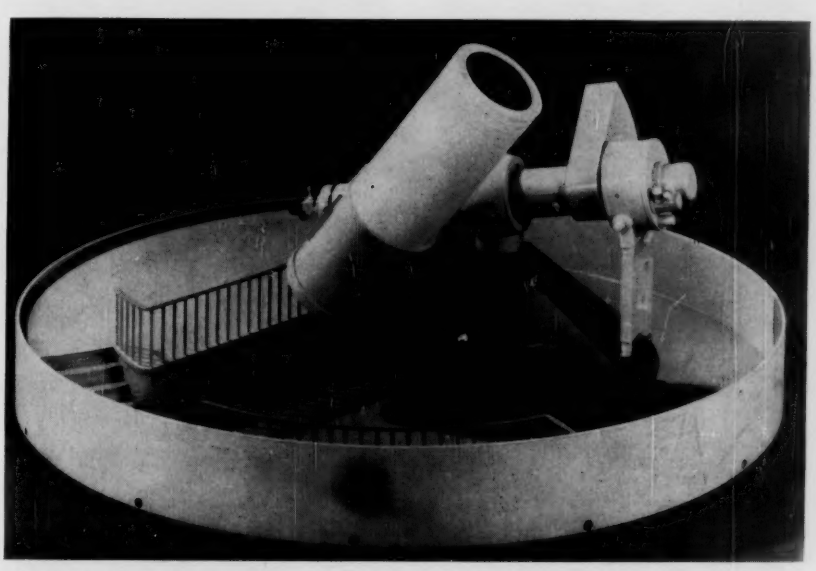
STUART J. INGLIS, *Contra Costa College*

FROM a location only a little more than 700 miles north of the equator, nearly all of the celestial sphere is visible throughout the year. Polaris is about 10 degrees above the northern horizon; the Southern Cross at its best is 20 degrees high in the south. With a latitude of only 10½° north, Caracas, Venezuela, is well situated for many astronomical research programs, and the government of the country is fully aware of this.

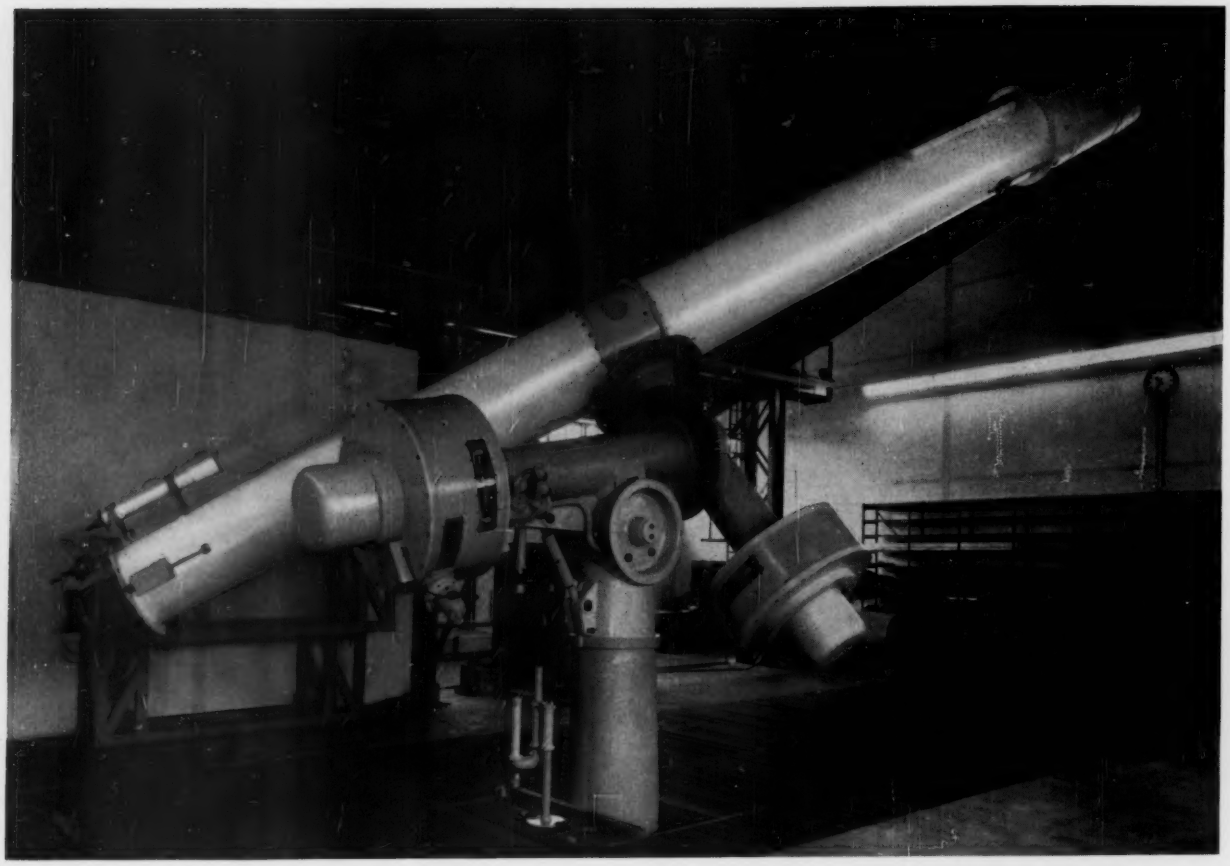
As a result, Venezuela is supporting a young and vigorous astronomical program. Under the guidance of Jose Abdala, director of the Cagigal Observatory, new instruments are being purchased and assembled, new buildings are being planned to house them, and new observing sites for telescopes are being sought.

Cagigal Observatory is located on a hill near the heart of Caracas, a large and modern city in every sense of the word. The present position is, therefore, not well suited for astronomical observations, and is used primarily for geophysical work. Instruments are being installed to record variations in the strength and direction of the earth's magnetic field. Not only is Caracas close to the magnetic equator, but it is also near the agonic line, along which a magnetic compass points simultaneously to the north geographic and north magnetic poles.

Several seismographs to measure earthquake waves in horizontal and vertical directions are in use or being installed; a special instrument is being set up to record large seismic disturbances. A gravimeter will measure the strength of



Orders have been placed with the Askania Works in Germany for several telescopes, among them an f/5 40-inch Cassegrainian-coude reflector, of which a model is pictured here. The counterweight is placed at the northern end of the polar axis, which has a special support because it is nearly horizontal.

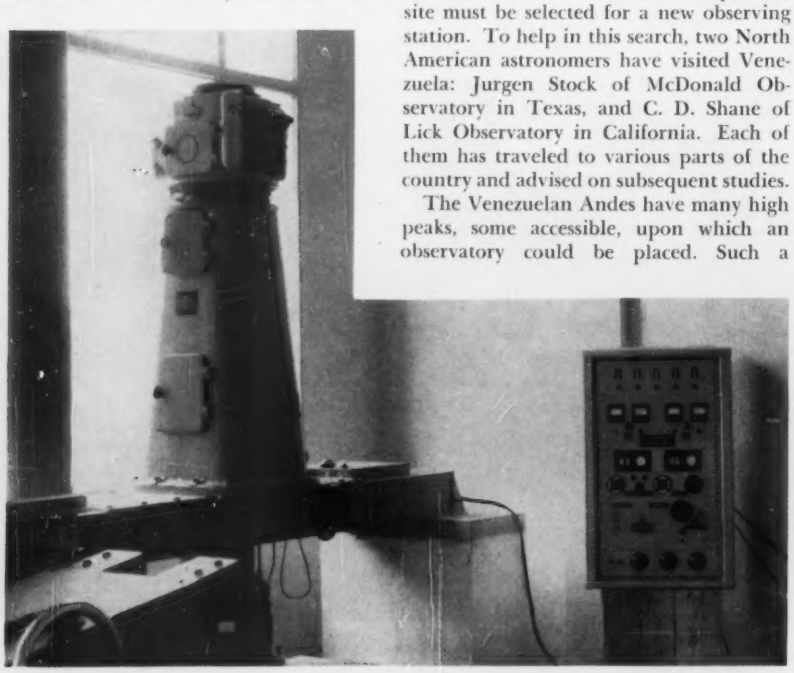


Only the top of the 25-foot pier for the 25.6-inch refractor is seen here. Windows in the counterweights reveal right ascension and declination driving-gear mechanisms. The polar axis is inclined only about 10 degrees. Carl Zeiss photo.

the earth's gravitational field at Caracas.

Location problems confronting the astronomer are not as easily solved as those of the geophysicist. Before any telescopes can be installed, buildings must be built for them, but first of all the best possible site must be selected for a new observing station. To help in this search, two North American astronomers have visited Venezuela: Jurgen Stock of McDonald Observatory in Texas, and C. D. Shane of Lick Observatory in California. Each of them has traveled to various parts of the country and advised on subsequent studies.

The Venezuelan Andes have many high peaks, some accessible, upon which an observatory could be placed. Such a site has many advantages during the dry season from October to April, but the rainy season would limit the number of observing nights. Therefore, a search for a suitable location elsewhere is being carried on at the present time; site surveys should be finished by the spring of 1962.



This photographic zenith tube, like many of the Cagigal instruments, is mounted temporarily in Caracas until a new observatory is built. Author's photograph.

The three places that now seem to be most promising are: 1. Picos de Chacopata on the Araya peninsula on the northeast coast of Venezuela. 2. Pico Alvarado, some 30 miles west of Barquisimeto, in the northwestern part of the country. 3. El Rodeo on the Paraguana peninsula on the northwest coast. However, seven other sites are being included in the study.

There are already many telescopes waiting to be installed once the new site is selected and the buildings constructed. First and foremost, a large Zeiss refractor of 25.6-inch aperture and 34.5-foot focal length will be mounted on a straight pier. Completed in 1959 after 3½ years work, it is the first telescope of this type to be built by Carl Zeiss, Oberkochen, West Germany. It is similar to Zeiss instruments of the same size in Berlin, Tokyo, and Belgrade.

The height of the pier is nearly 25 feet, and the length of the telescope's tube 38 feet, requiring a dome roughly 50 feet in diameter. The mounting and

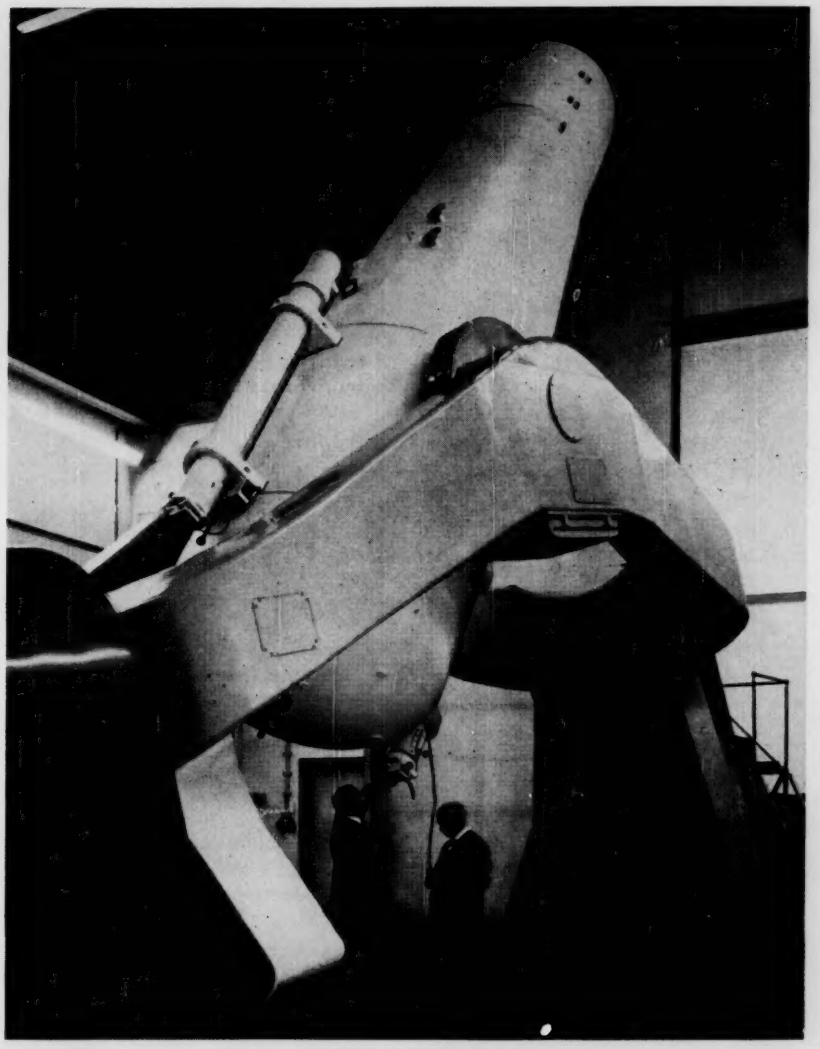
telescope together weigh about 17 tons. A number of accessories and supplementary instruments will permit an extensive observing program, including work on the sun, double stars, and celestial photography.

The large refractor will be accompanied by a 40-inch Schmidt camera, upon which can be placed a four-degree objective prism. A 40-inch f/5 Cassegrainian-coude reflecting telescope is part of the equipment being purchased from the Askania Works in Berlin. Other instruments are a 20-inch double astrograph (f/9), two meridian circles (one of them portable), and a photographic zenith tube (pictured on the facing page).

Astrometry is one of the fields emphasized in the Cagigal program. From Venezuela, absolute determinations of fundamental positions can be made for stars over most of the Northern and Southern Hemispheres. This will serve to tie several systems of fundamental star positions together. Francis P. Scott, who is in charge of the 7-inch meridian circle at the U. S. Naval Observatory, has visited Caracas as a consultant on the astrometry equipment.

The Venezuelan Central University in Caracas plans to develop an astronomical curriculum, and two telescopes for student use have been obtained: an 8-inch f/14 refractor and a small meridian instrument. A teaching program is urgent, for there are few trained astronomers in Venezuela to fill the many posts that will become available in the near future. Astronomers with a knowledge of the Spanish language are scarce.

To build up and maintain public interest in the astronomical program, a large planetarium with a Zeiss projector has been completed (see front cover). It is located in a delightful park in the suburbs to the east of Caracas, and can attract visitors from among the one million residents of the metropolitan area. The planetarium is operated by the observatory, so Dr. Abdala is also faced with the problem of finding competent lecturers for the public showings.



This is one of the largest Schmidt telescopes in the world, built by Askania for Venezuela. The mirror's diameter is 152 centimeters (60 inches), the correcting lens 100 centimeters; the focal length is 300 centimeters. The mounting is a variant of the double fork or bent yoke, with two counterweights, the northern one (right of center) being cut away to permit observation of the celestial pole. Two guide telescopes are provided. For four years 40 engineers, physicists, and machinists worked on this telescope project, the designs requiring 72 volumes of engineering and optical drawings, 250 to a volume. The Palomar Observatory Schmidt is only eight inches greater in aperture than this instrument, and its mirror 12 inches larger. Askania photograph.

CHANGES IN ATMOSPHERIC DRAG

Most artificial satellites move so close to the earth that the friction of the atmosphere has a considerable effect on their motions. In the April issue of the *Review* of the Society for Industrial and Applied Mathematics, G. M. Clemence of the U. S. Naval Observatory points out that gravitational and drag effects on a satellite's orbit can only be imperfectly separated, making predictions of future positions difficult. He writes, in part:

"The atmosphere has turned out to be very different from what most persons supposed three years ago [before Sputnik I]. At that time it was generally believed that a static model would suffice, and that its effect on satellite motion could be completely specified by stating a simple relation between density and height above the earth's surface. It was thought that such a relation could be established by observations of a few satellites. What has in fact been established is that the drag-effect on a satellite caused by friction with the atmosphere is continuously varying in an unpredictable fashion. The variations amount to a substantial fraction of the entire amount of the drag at a height of 150 miles, and the percentage-variation increases with increasing height, so that at 400 or 500 miles the effect varies by several times its minimum amount."

Pointing out that the variations are strongly correlated with solar activity, Dr. Clemence goes on to say, "It is impossible to predict the motions of satellites within a few hundred miles of the earth, with a precision comparable to that of the observations, for more than a few weeks in advance. And there is no artificial satellite for which a complete theory of the motion exists. What has been done in practice is to construct separate theories for every satellite, each theory representing the motion over a few weeks at most; it has not been possible to join the separate theories together, so as to provide a continuous representation of the motion. The outlook for future improvement in the prediction process is a bleak one. It can hardly be doubted that the variations in solar activity are for the most part of a statistical nature, caused by convective and radiative processes within the sun that have to be regarded as randomly occurring phenomena."

Astronomical Notes from Berkeley—2

Standard Terminology for Meteoric Astronomy

To clarify and standardize the terms used to describe meteor phenomena, a special subcommission was formed three years ago in the International Astronomical Union. Under the chairmanship of the Canadian astronomer Peter M. Millman, this group prepared a list of terms and definitions that was approved last summer by the IAU in Berkeley. The following is a brief report by the chairman, introducing the lists of adopted words.

"During the last decade the contact between astronomy and other scientific disciplines, and also between astronomy and the general public, has increased so rapidly that it is important to have a perfectly clear understanding of the meaning of basic astronomical terms. The definition of equivalent terms in various languages also needs careful consideration. This is particularly necessary in the study of meteors, since here we have a field where the work of the amateur and the observations of the layman have especial significance.

"The group responsible for this work agreed that it was better to start with a fairly short list of very basic terms and to reach agreement on these. This first list can be extended later if need arises. The philosophy which governed the formation of our listings was to retain the standard usage of words wherever possible, and to give definitions which would be clear to the nonspecialist and which would have a reasonable leeway in interpretation. The necessity of finding equivalent terms in four different languages imposed certain restrictions on the words selected for the table below. For example, the English word *trail,* though frequently used in the past, has not been included, since there is only one Russian word след as a translation for the two English words *trail* and *train.* Where a specific word is desired for reference to the photographed path of a meteor, *track* can be used.

"It is recommended that when words like *telescopic, visual,* and *photographic* are used with *meteor* they should refer only to the observational technique used in recording the phenomenon, and that they should not be used as an indication of brightness or size. Such words as *bright, faint, large,* and *small* may be used qualitatively with their normal meanings. To describe a specific range of brightness or size in quantitative terms, standard units such as magnitude, millimeter, and kilogram should be employed. To find the *absolute magnitude* of a meteor the *apparent magnitude* must be corrected both for distance, to bring the meteor to a standard distance of 100 kilometers, and for absorption, to reduce the meteor to a standard absorption of one vertical atmosphere."

Peter M. Millman, of the National Research Council of Canada, has provided the accompanying report on international meteoric terminology.

Basic Definitions in Meteoric Astronomy

A. *meteor* — in particular, the light phenomenon which results from the entry into the earth's atmosphere of a solid particle from space; more generally, as a noun or an adjective, any physical object or phenomenon associated with such an event.

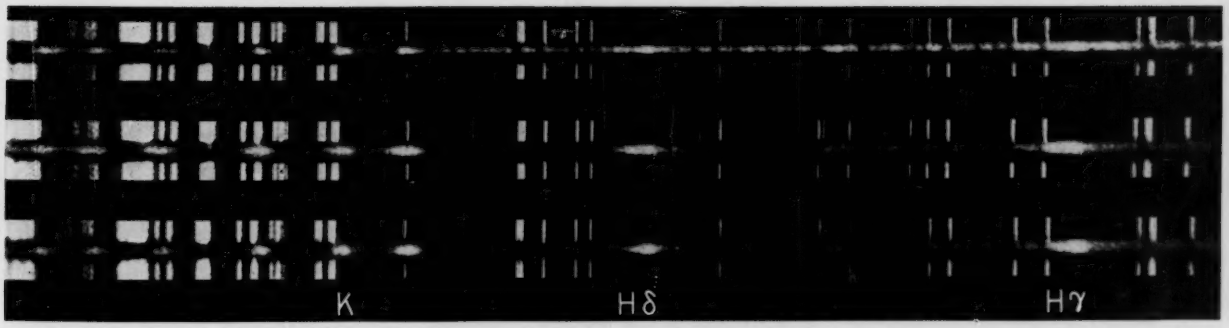
B. *meteoroid* — a solid object moving in interplanetary space, of a size considerably smaller than an asteroid and considerably larger than an atom or molecule.

C. *meteorite* — any object defined under B which has reached the surface of the earth without being completely vaporized.

D. *meteoric* — the adjectival form pertaining to definitions A and B.

Terms Recommended for Use in Meteoric Astronomy

	English	*French*	*Russian*	*German*
A.	meteor shooting star	météore étoile filante	метеор падающая звезда	Meteor Sternschnuppe
B.	meteoric body meteoric particle meteoroid	corps météorique particule météorique	метеорное тело метеорная частица	Meteorkörper Meteorteilchen
C.	meteorite	météorite	метеорит	Meteorit
D.	meteoric	météorique	метеорный	meteorisch Meteor-
E.	meteoritic	météoritique	метеоритный	meteoritisch
F.	bolide fireball	bolide	болид	Feuerkugel
G.	micrometeorite	micrométéorite	микрометеорит	Mikrometeorit
H.	dust	poussière	пыль	Staub
J.	absolute magnitude	magnitude absolue	абсолютная величина	Absolutgrösse
K.	trajectory	trajectoire	траектория	Trajektorie; atmosphärische Bahn
L.	path	trajectoire apparente	путь	Bahnspur scheinbare Bahn
M.	train	traînée	след	Schweif
N.	persistent enduring	persistant	длительный долговременный	andauernd
O.	wake	sillage	хвост кратковременный след	Schweifansatz
P.	radiant	radiant	радиант	Radiant; Ausstrahlungspunkt
Q.	earth-point	point terrestre	земная точка	Erdpunkt
R.	zenith attraction	attraction zénithale	зенитное притяжение	Zenitverschiebung Zenitattraktion
S.	orbit	orbite	орбита	Bahn
T.	shower	averse	поток дождь	Schauer
U.	stream	essaim courant	рой	Strom



Three spectrograms of AE Aquarii, part of a series taken on August 14, 1960, with the 120-inch reflector. Beginning at the top, they were made during the time intervals indicated by brackets on the photoelectric light curve reproduced below. The first spectrum spanned a minimum of light, the second a maximum, and the third a decline in brightness. Two hydrogen emission lines and the K line of ionized calcium are labeled. Violet is to the left, red to the right. Each stellar spectrum lies between bright-line spectra from a laboratory source. Lick Observatory photographs.

E. *meteoritic* — the adjectival form pertaining to definition C.

F. *fireball* — a bright meteor with luminosity which equals or exceeds that of the brightest planets.

G. *micrometeorite* — a very small meteorite or meteoritic particle with a diameter in general less than a millimeter.

H. *dust* — when used with D or E — finely divided solid matter, with particle sizes in general smaller than micrometeorites.

J. *absolute magnitude* — the stellar magnitude any meteor would have if placed in the observer's zenith at a height of 100 kilometers.

K. *trajectory* — the line of motion of the meteor relative to the earth, considered in three dimensions.

L. *path* — the projection of the trajectory on the celestial sphere, as seen by the observer.

M. *train* — anything (such as light or ionization) left along the trajectory of the meteor after the head of the meteor has passed.

N. *persistent* — an adjectival form for use with M indicating durations of some appreciable length.

O. *wake* — train phenomena of very short duration, in general much less than a second.

P. *radiant* — the point where the backward projection of the meteor trajectory intersects the celestial sphere.

Q. *earth-point* — the point where the forward, straight-line projection of the meteor trajectory intersects the surface of the earth.

R. *zenith attraction* — the effect of the earth's gravity on a meteoric body, increasing the velocity and moving the radiant toward the zenith.

S. *orbit* — the line of motion of a meteoric body when plotted with reference to the sun as origin of co-ordinates.

T. *shower* — for use with A or D — a number of meteors with approximately parallel trajectories.

U. *stream* — for use with A or D — a group of meteoric bodies with nearly identical orbits.

Spectra of AE Aquarii

Among the exhibits on display at Lick Observatory for visiting delegates from the International Astronomical Union were spectrograms and a light curve of the remarkable variable star AE Aquarii. It is unique in having incessant irregular outbursts of brightness, following one another at intervals from a few minutes up to an hour. An added peculiarity is that the star is a spectroscopic binary, having a 0.70-day period.

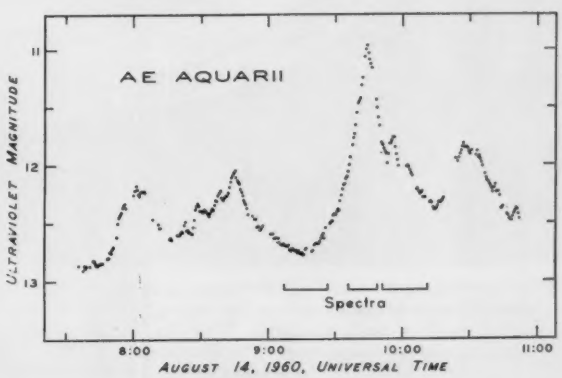
To help explain the complex behavior of AE Aquarii, Lick astronomers have been making simultaneous photometric and spectrographic observations. The accompanying ultraviolet light curve was obtained last year by A. E. Whitford with a photoelectric photometer attached to the 36-inch Crossley reflector. His observations were immediately reported by telephone to the dome of the 120-inch reflector, where Merle Walker was taking spectrograms. In this way, Dr. Walker could know when to observe, and could suit his exposure times to the changing brightness of the star.

The spectra were formed by a grating and a 20-inch Schmidt camera at the coude focus of the 120-inch instrument. But even with such a large telescope, AE Aquarii is a faint star for spectroscopic work, and at the same time the rapidity of its variations calls for short exposures. Hence the spectra were recorded with the newly developed Lallemand electronic camera, the final dispersion being 65 angstroms per milllimeter. The electronic amplification made it possible to limit the exposures to 20 or 30 minutes when the star was near minimum light and 12 to 15 minutes when it was bright.

Concerted observations of this kind show the complexity of the star's behavior, for before one outburst has ended another has begun, making it difficult to isolate the course of events during a single "explosion." Dr. Walker points out that the spectra reproduced here provide a fairly clear-cut example of the changes that take place between minimum and maximum light.

In general, the emission lines of hydrogen and ionized calcium become much stronger and broader, and the late-type absorption spectrum of the *K*-type secondary star becomes filled in by continuous emission from a hot source. Comparing the first two spectra, we see that the hydrogen lines are broadened asymmetrically as the light increases, in this case toward shorter wave lengths. During other explosions, however, broadening to the red or to both red and violet has been observed.

These facts indicate that the explosions occur in localized areas of the AE Aquarii binary system. Many more observations are needed to determine the nature of the explosive process, and to ascertain the parts of the system in which outbursts originate more frequently.



A portion of a photoelectric light curve for AE Aquarii. Each dot is a measurement with the 36-inch Crossley reflector of Lick Observatory. Bars labeled "Spectra" indicate exposure durations for the three photographs above.

GETTING ACQUAINTED WITH ASTRONOMY

THE PLANETS — SATURN – II*

NEARLY every amateur astronomer can remember when and where he caught his first sight of the rings of Saturn in a telescope. The striking beauty and remarkable form of the planet's appendage make a deep and lasting impression. Even though the rings have been long observed with large telescopes and studied by theoreticians, they still present many unsolved problems.

The planet is surrounded by a system of at least three concentric rings. The outer, **A** ring has a diameter of 171,000 miles and is about 10,000 miles in breadth. The narrow, dark Cassini division separates it from the brighter **B** ring, 16,000 miles wide. Within this is the much fainter crape ring, **C**, which reaches to about 7,000 miles from the equatorial surface of the planet.

Is there a fourth ring exterior to the others? In 1907 the skillful French observer G. Fournier reported seeing a very dim fringe bordering **A**, and soon afterward other sightings of it were made by E. Schaer in Switzerland and at Greenwich Observatory. E. E. Barnard, however, could not recognize it with the Yerkes 40-inch refractor. During recent years, a number of British and American amateurs have again announced observations of the enigmatic **D** ring, some of their views of it being with telescopes as small as 6-inch aperture.

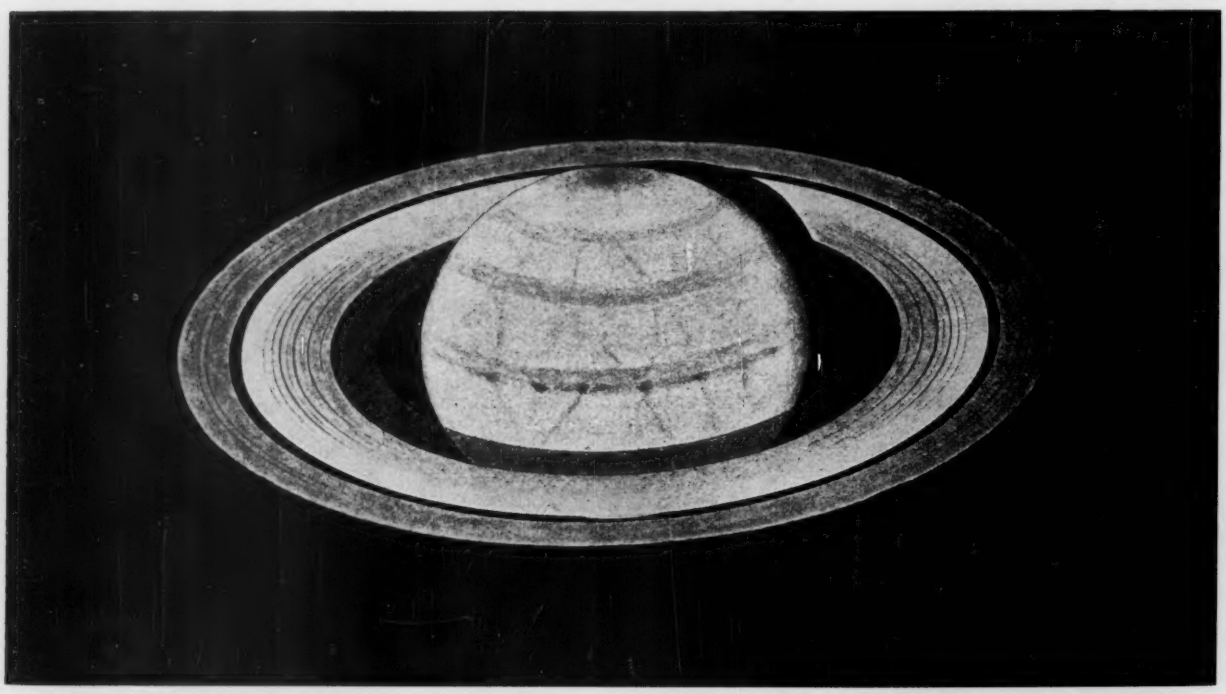
There are many proofs that the ring system is composed of a host of small bodies rather than a solid sheet. J. E. Keeler demonstrated long ago by spectrographic observations that the outer edge of the ring system is revolving around Saturn more slowly than the inner edge, the revolution periods matching those predicted by Kepler's third law for moonlets moving freely around the planet. Another line of evidence is a brightening of the rings when Saturn is exactly in opposition to the sun. This is the effect to be expected from a swarm of small bodies, for at that time each particle's shadow lies concealed behind it. The most direct proof of all is the partial transparency of the crape ring, through which the ball of the planet can be seen.

Careful photometric studies of the ring system have been made recently by M. S. Bobrov in Russia and by F. A. Franklin and A. F. Cook II in the United States. The average size of the small bodies is between 10 centimeters and 10 meters, according to Bobrov, who believes that the total mass of the rings is between 4×10^{-8} and 4×10^{-7} that of the planet itself. Franklin and Cook, however, feel that the photometric data are not yet adequate to permit safe conclusions as to particle sizes. The high reflecting power of the rings has suggested that they are composed of icy rather than rocky fragments. This has been confirmed by G. P. Kuiper's observation that the infrared spectrum of the rings shows absorption features characteristic of frost.

During Saturn's 29½-year circuit of the sun, the ring system is twice presented edgewise and twice opened to its widest extent. On the former occasions, the earth may pass through the ring plane three times within a few months. In September, 1959, the rings were fully opened, with the earth 26.7 degrees north of their plane, as viewed from the center of Saturn. At present and during the next few years, our view of the rings is becoming more and more oblique. Finally, according to J. G. Porter's predictions, on December 13, 1965, the earth will pass through the plane of the rings, which will then be invisible because of their exceeding thinness. During the next month, until January 12, 1966, the earth and sun are on opposite sides of the plane, and we will have the dark side of the system turned toward us.

After that, both earth and sun will lie to the north of the plane until June 15th, when the sun's passage through it to the south side will cause a second interval of invisibility. This lasts until August 22, 1966, after which the sunlit southern

*Part I, dealing with the planet itself, appeared in the September issue, page 138. Information on observing Saturn's satellites was given on page 336 in June.



Percival Lowell's drawing of Saturn summarizes the extensive observations by him and E. C. Slipher with Lowell Observatory's 24-inch refractor during the spring of 1915. At that time the rings were opened to their widest extent, facilitating detailed study of their structure. Note the shadow of the ball on the rings, and the visibility of Saturn itself through the semitransparent crape ring. The delicate markings on the disk are drawn in Lowell's characteristic style. This picture is a reproduction of the frontispiece in his "Memoir on Saturn's Rings," 1915.

face of the rings will be tipped toward the earth.

This sequence of changes will provide fascinating observing, especially in large telescopes. Amateur records of the visibility or nonvisibility of the rings from night to night during that period can have considerable scientific value. For example, they may give a very sensitive check on the orientation of the ring system in space, and information about its thickness. In 1956 Bobrov published an analysis of the previous records of ring disappearances, from which he concluded that the thickness of the system was at most 20 kilometers, and possibly as little as 100 meters.

Saturn observers have devoted much attention in recent years to the divisions in the ring system, one of which, Cassini's, can be readily seen in a 3-inch refractor. There have been a number of records of slight raggedness in the inner edge of **A**, adjoining the Cassini division. This effect can be noted in Fournier's drawing of February 15, 1914, reproduced on page 139 of the September issue.

Less conspicuous divisions are numerous, Percival Lowell having drawn three in **A** and seven in **B** during his 1915 observations with the 24-inch refractor at Lowell Observatory. However Kuiper, who restricts the term "division" to actual gaps, finds that only the Cassini feature is a division in this sense. The others, he has noted, are boundaries between concentric regions of different brightness. His conclusions were reached from observations on an excellent night in 1954, with the 200-inch Palomar reflector and a power of 1,170.

Nevertheless, the word "division" has remained in widespread use as a convenient way of referring to the concentric markings on the rings. Several years ago Walter Haas suggested a nomenclature for these features based upon location. For example, **A5** means a division in ring **A**, five tenths of the way from its inner to its outer edge. **A5**, by the way, is Encke's division, discovered over a century ago with the 9½-inch refractor of Berlin Observatory, and visible with smaller apertures when the rings are not too foreshortened.

In these three aspects of the ring system, the presentation varies from edgewise to fullest view of the southern face. They correspond to the appearance in 1965-66, 1970, and 1974, respectively. After R. A. Proctor.

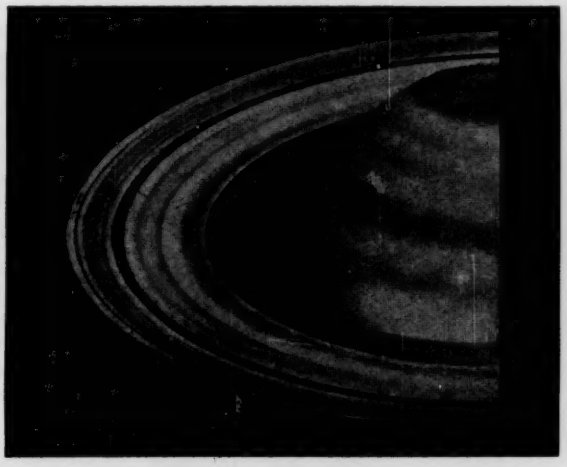
The Haas nomenclature is in regular use by members of the Association of Lunar and Planetary Observers. In summarizing their recent Saturn work, Thomas Cragg refers to records of five divisions, **C5**, **B0**, **B3**, **B5**, and **B7**, in addition to Cassini's and Encke's. These minor features, he points out, are normally very difficult to see, and require the best observing conditions even with large telescopes. They are seen more readily near the extremities of the ring than where it crosses the planet.

On rare occasions, the occultation of a fairly bright star by Saturn's rings can be observed. Such an event is a very powerful means for probing the structure of the ring system. In 1917 the British amateurs M. A. Ainslie and J. Knight watched a 7th-magnitude star pass behind **A** and Cassini's division. The star appeared faintly through **A**, but twice brightened up for a few seconds, and seemed to regain its full light when seen through Cassini's division.

Every effort should be made to obtain detailed observations of future occultations by the rings. A large telescope is desirable, for existing evidence indicates that a 12-inch telescope is needed to see an 8th-magnitude star through ring **B**, except when passing a division. Accurate times should be recorded for contacts of the star with ring boundaries or the planet's limb, and for any brightenings while the star is behind the rings.

Of even greater importance would be watching the eclipse of a satellite by the ring system. Only one observation of this kind is on record, an eclipse of Iapetus on November 1, 1889, that was seen by Barnard at Lick Observatory. After Iapetus emerged from eclipse by the planet, Barnard made frequent estimates of its brightness relative to Tethys and Enceladus, while the satellite was shadowed by the crape ring. He could keep Iapetus steadily in view until it entered the deeper shadow of ring **B**.

Another ring eclipse of Iapetus was predicted for May 15, 1907, but seems to have gone unobserved. The next of these rare opportunities should not be missed.



Compare the ring details in this Pic du Midi Observatory drawing with those in the Lowell drawing on the facing page. This view is based on observations with a 24-inch refractor at 900x, under very favorable conditions. The relative dimensions in this delineation are from measurements with a double-image micrometer. From "L'Astronomie" for January, 1953.

LETTERS

Sir:

Page 159 of SKY AND TELESCOPE for September speaks of "the first telescope made by Hans Lippershey in 1608," thereby repeating a widespread error concerning the invention of this instrument.

The Dutch scholar C. de Waard, Jr. (*The Invention of Telescopes,* 1906), brought to light that Lippershey, who applied for a patent on the telescope, was not the original inventor, nor were Metius and Janssen, two other Dutch patent applicants.

De Waard proved that both Lippershey and Metius knew that Janssen made a telescope before they did. But in 1634, Janssen's son told the Dutch physician and scientist Isaac Beeckman that his father in 1604 was the first in Holland to make a telescope, after the model of an Italian soldier's telescope, which was inscribed "Anno 1590."

Beeckman's evidence, which is fully trustworthy, did not come to light until about the year 1900. Unfortunately, de Waard's book has been published only in Dutch. Hence it is at most known by name to foreign authorities, who keep mentioning Lippershey or Janssen as the inventor of the telescope.

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A 200-inch photograph of part of the Hercules cluster of galaxies, about 400 million light-years distant. Most of its members are spirals and irregular systems. The internal motions in this cluster have led to the suspicion that it is expanding. One minute of arc is marked at lower left.

IAU Symposium on Galaxies

JOHN B. IRWIN, *Goethe Link Observatory, Indiana University*

PROBLEMS of extragalactic research were considered by 130 astronomers from 15 nations at the International Astronomical Union's 15th symposium, held August 10-12 on the campus of the University of California at Santa Barbara. As might be expected from the many contributions to this subject by the giant California reflectors, more than one fourth of the participants were from that state.

The symposium was preceded on August 8-9 by a conference on the instability of systems of galaxies, sponsored by the Berkeley Statistical Laboratory of the University of California and by Van Vleck Observatory of Wesleyan University, with National Science Foundation support. The conference's organizing committee was J. Neyman, T. L. Page, and Miss E. L. Scott. Notes on the papers were prepared by Dr. Page and O. Heckmann, and are drawn upon for this report.

The masses of galaxies occupied a fundamental place in the discussions. There are two different ways of evaluating a galaxy's mass, first by studying its rotation from radial velocity observations at different distances from the center, and second by studying differences in radial velocity among members of the same cluster of galaxies. In the latter case, the mass derived is an average value; in both cases, the observations of these faint objects are difficult and lengthy even with the largest telescopes.

In a general way, we can expect the observed velocities to increase with mass. For example, if the sun's mass were 100 times as great as it is now, the earth, at its present distance from the sun, would move 10 times faster in its orbit, making the year only 36.5 days long. If instead of just two bodies, we consider a cluster of 100 or 1,000 objects, perhaps of greatly differing masses, we will be dealing with not a single velocity but with a wide range or dispersion of velocities in the cluster. The greater the average mass, the larger the internal velocities and the range in velocities will be. This is true even if only one component of the velocities — along the line toward and away from the observer — is considered or measured.

A cluster that is not stable but expanding is said to have a *positive total energy*, and the dispersion of its members' velocities will be larger than in the case for stability. If an astronomer incorrectly assumes an expanding cluster to be stable, he will derive from his observations a fictitiously large average mass for the cluster members. The masses of galaxies as deduced from velocity dispersions in clusters are considerably larger than the masses derived from their internal rotations, and this fact has cast doubt on cluster stability.

Some years ago, V. A. Ambartsumian of Burakan Observatory, who is now president of the IAU, showed that there are unstable groups of *O*- and *B*-type stars which he called associations. These have positive total energies and are therefore unstable and expanding. The time since the beginning of expansion is short, and the stars in an association must be young. More recently, Dr. Ambartsumian has suggested that some clusters of *galaxies* have positive total energy. The rate of expansion of a cluster can be calculated from its present size and a knowledge of the internal velocities.

The results of such calculations imply that both spiral and elliptical galaxies have evolutionary lives as short as 10^8 or 10^9 years — an uncomfortable surprise for astronomers. To start the expansion, an enormous energy release would be required, greater than given by any process now observed or clearly postulated. Strong extragalactic radio sources have been tentatively identified with these "violent explosions," which may also explain the formation of spiral arms and of small groups of galaxies.

There is, however, an alternative to Dr. Ambartsumian's hypothesis. From the assumption that 99 per cent of the matter in the universe is in the form of an invisible intergalactic medium, it would follow that the clusters of galaxies are stable. The unseen material would add enough mass to a cluster to explain the high velocities of its members relative to each other. With this viewpoint, radio sources could be explained as collisions between galaxies, and spiral arms as caused by magnetic fields in interstellar plasmas. A primary purpose of the conference was to discuss the theoretical and observational evidence pertinent to these differing interpretations.

Another Burakan astronomer, B. E. Markarian, reported on a striking chain of eight bright galaxies in the Virgo cluster, a slightly curved line extending over a degree and a half. It is highly improbable that eight galaxies could form such a chain without being physically connected, but an extended array of this type can hardly be stable. The assumption of stability would lead to an unacceptably huge mass, some 4×10^{13} suns, for one of the member galaxies, NGC 4406; the average luminosity per unit mass would be only about 1/1,000 as much as for the sun. Hence Dr. Markarian argued that this chain of galaxies is unstable, lending support to Dr. Ambartsumian's theory.

Any investigation of the velocities of galaxies in a cluster or small group is complicated by the possibility that nonmembers lying in the same direction have been mistaken for members. But now H. Spinrad, University of California, has recognized a strong correlation between absolute magnitudes of galaxies and the intensities of the sodium D absorption lines in their spectra. This spectroscopic

criterion could be very useful in distinguishing foreground or background objects from cluster members. Such field galaxies have greatly differing radial velocities and are often the cause of large uncertainties in evaluating a cluster's total energy.

The velocity dispersion of galaxies in the Virgo cluster is so high that it leads to anomalously large masses. An entirely different explanation of this was offered by E. Holmberg of Uppsala Observatory in Sweden. He suggested that the high dispersion was spurious and due to a combination of systematic errors in the red shifts, orbital motions within subgroups such as double or multiple galaxies, and the inclusion of nonmembers. The systematic red-shift errors, which may amount to several hundred kilometers per second, appear to be correlated in some way with the nucleus brightnesses of the measured systems. But N. U. Mayall of Kitt Peak Observatory expressed much doubt that there could be systematic errors of the measured radial velocities as large as those suggested by Dr. Holmberg.

The entire problem needs to be studied further with the new, stable, fast, and relatively high-dispersion nebular spectrographs now in operation, for example at Palomar Observatory. At present, eight open spirals (type Sc) in the Virgo cluster with emission lines in their spectra have a mean recession of 1,100 ± 150 kilometers per second, whereas 10 Sc galaxies with no emission lines give 1,800 ± 250. This large systematic difference between the two types of galaxies is very difficult to explain, if it is real.

G. B. van Albada, Astronomical Institute of Amsterdam, described calculations showing that a cluster of galaxies, under gravitational forces, will develop in 20 billion years a rather dense, nearly homogeneous core surrounded by an extended corona. A comparison with Dr. Mayall's velocity distribution for the Coma cluster showed good agreement. These theoretical results were obtained with a large electronic computer, as were other calculations by Stockholm astronomer P. O. Lindblad. In a motion picture based on his results, he showed how spiral arms might be formed in a galaxy by a perturbation of its gravitational field. One second of film time corresponded to eight million years, and in 10^9 years the spiral arms were seen to form, first leading, then to disappear, and later to form again, this time trailing.

Dr. Heckmann, of Hamburg Observatory, considered the possible effects of a general rotation in the early stages of an expanding universe. There exists, within the framework of Newtonian cosmology, a model in which a major stumbling block — the need for an enormous central density at some finite time in the past — may be removed by introducing a rotation now amounting to about one second of arc in 10 million years. Although there are

F. Zwicky found this very remote supernova, nearly a billion light-years away. Of magnitude 18 on this 200-inch photograph, the new star was nevertheless much brighter than its galaxy.

difficulties in deriving a corresponding Einsteinian model, there seems to be some possibility that the expansion of the universe did not necessarily begin explosively. If this is so, then recently derived discrepancies between a cluster age of 25×10^9 years and an "age of the universe" of considerably less need not be taken too seriously.

Some important observational advances noted during the symposium were W. W. Morgan's new data on classification of galaxies, B. A. Vorontsov-Velyaminov's atlas of interacting galaxies, and the new Hubble atlas prepared by A. R. Sandage. These pictorial collections emphasize how different galaxies may be, one from another, and how little we understand the processes determining their evolution.

Questions asked but not answered were: Why has star formation been completed in all kinds of elliptical galaxies, from giants down to Sculptor-type systems? Why has it not been completed in spirals, whose nuclei are much like those of ellipticals? Are the spiral shapes due to gravitation, or do gas dynamics and magnetohydrodynamics play the main role? How can spiral structure persist for 10^{10} years, especially in systems with rapid differential rotation? What happens in the halo during the general circulation of gas through a spiral? Are there significant numbers of hydrogen *molecules* in interstellar space?

Otto Heckmann, director of Hamburg Observatory in West Germany, is a leading investigator of cosmology.

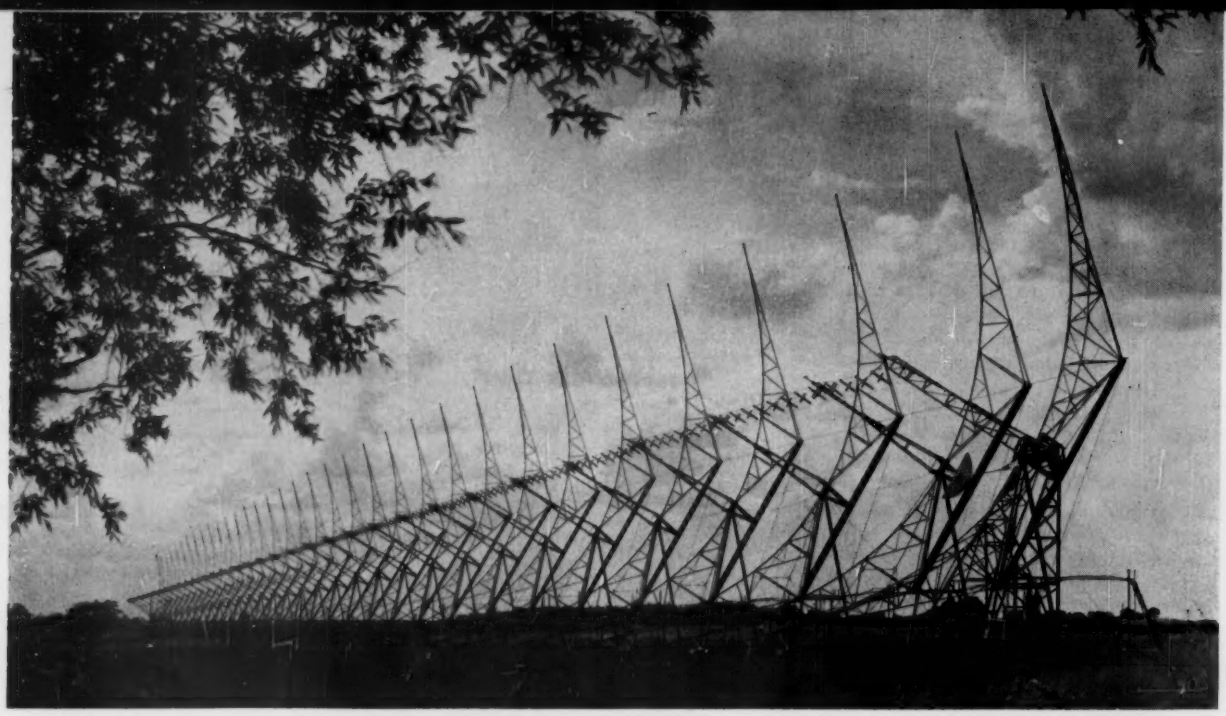
New phenomena concerning interstellar gas have been found recently by Dutch radio observations of the central region of our galaxy and from coude spectra near the nucleus of the Andromeda nebula. In the Milky Way system, the gas moves outward from the center between 100 and 200 kilometers per second, providing good evidence of magnetic fields strong enough to "push" spiral arms away from the center at these speeds.

Rotational motions observed in a small disk of hydrogen within 600 parsecs of the center indicate a high central concentration of mass, a result rather similar to what is found in M31 by Guido Münch of California Institute of Technology. Dr. Münch also reported that none of the luminous knots in the disk of the Sombrero nebula (NGC 4594) show emission lines. This result is in striking contrast to other galaxies, where such knots have been identified with large emission-type gaseous nebulosities.

In recent years there has been much uncertainty about the amount of the Hubble constant, which specifies the rate at which the recessional velocities of galaxies increase with distance. A new value of 98 ± 15 kilometers per second per megaparsec has been derived by Mount Wilson's Dr. Sandage, from his own work and from independent studies by J. L. Sersic of Cordoba Observatory, S. van den Bergh of David Dunlap Observatory, and Dr. Holmberg. Yet these investigations all depend on the same period-luminosity relation for classical Cepheid variable stars, to calibrate the scale of galaxy distances. The zero point of this relation, as used by Dr. Sandage, is defined by five Cepheids in open star clusters, and has recently been changed to make the Cepheids almost a quarter of a magnitude more luminous than was previously thought. But there is growing evidence that Cepheids of the same period but in different galaxies do not have identical luminosities or colors.

The study of supernovae has taken a surprising new turn at Palomar Observatory with the discovery by F. Zwicky of three new objects whose light curves are entirely different from either Type I or II supernovae. One of the three, at an estimated distance of nearly a billion light years, is the most distant supernova ever recorded; although of 18th magnitude it was about 10 times brighter than the exceedingly faint dwarf galaxy in which it occurred. Its featureless continuous spectrum resembles those of blue stars of spectral class *O*.

Caltech radio astronomers, working with the twin 90-foot antennas in Owens Valley, California, find that, unexplainedly, very many of the brighter extragalac-



The fixed east-west array of the Cambridge interferometric telescope has 34 unit parabolas, each 65 feet in aperture. A movable aerial of six units operates half a mile away, the arrays together having the same resolution as two 750-foot paraboloids that same distance apart. Photograph by Stearn and Sons, courtesy British Information Services.

tic radio sources are double. The components' separation is often startlingly larger than the optical size of the single galaxy that is presumably the cause of the radio emission. H. P. Palmer presented recent Jodrell Bank transit-interferometer measures at 1.89 meters of radio source diameters. The four base lines used were as long as 2,200, 9,700, 32,000, and 62,000 wave lengths. Only seven of the 246 bright sources examined were unresolved at any base line, indicating for them diameters of less than two seconds of arc.

One of these very small sources (3C-48) has been provisionally identified with a remarkable optical star that has faint traces of nebulosity (SKY AND TELESCOPE, March, 1961, page 148, and September, 1961, page 131). Most of the sources appear to have *two* major components, and in some cases these are separated by more than the diameter of either member. This circumstance, plus the fact that all observations were made at similar position angles, makes interpretation difficult, but it seems that most of these sources have angular diameters of the order of 30 seconds of arc. The strong radio emission combined with this small angular area leads to estimates of radio surface brightness corresponding to a temperature of about 30 million degrees Kelvin.

A most important paper which provoked vigorous discussion was that by Martin Ryle, of the Cavendish Laboratory in Cambridge, England, who presented an analysis of recent radio surveys at 178 megacycles (corresponding to a wave length of 1.7 meters). In some respects, today's situation in radio astronomy resembles that of optical astronomy a century ago, when the positions of only a few thousand bright stars were accurately known. But F. Argelander was then systematically cataloguing the approximate positions and magnitudes of 324,000 stars as a basis for later, more refined investigation, and his great *Bonner Durchmusterung* was completed in 1862.

The present radio surveys face far greater difficulties than those Argelander met, and require radio telescopes that are complex, expensive, and so large that their sizes may be expressed in acres or miles. The low resolving power of radio telescopes introduces three main difficulties in survey work: poor positional accuracy, hampering identifications with optical objects, such as nebulae and galaxies; the unresolved complex structure of many radio sources; and overlapping of sources.

To improve sensitivity and especially resolving power, a new interferometric radio telescope of greater power than any previous instrument was completed in 1958 at Cambridge's Mullard Radio Astronomy Observatory. The east-west half of the antenna, pictured here, is fixed and is a cylindrical paraboloid 65 feet wide and 1,450 feet long. The north-south half is an array 190 feet long by 65 feet, which can be shifted from time to time on railway tracks; in three weeks of observing it can effectively cover an area on the ground of 1,000 by 190 feet, for a given strip of declination. The output of the receiver is recorded directly on tape, which is then fed into an electronic computer to make the complicated analysis of the observations.

The high sensitivity of this radio telescope is shown by the fact that radio source 3C-295, a pair of colliding galaxies near the limit of detectability of the 200-inch Hale reflector, is "off-scale" for the Cambridge instrument. This object has a red shift 46 per cent of the speed of light. Dr. Ryle believes that some of his fainter sources are so distant and have such large red shifts that optically the Lyman-alpha hydrogen line (1216 angstroms) should be displaced into the observable ultraviolet.

A primary purpose of the Cambridge surveys is to learn how the sources are distributed in space. Consider first the numbers of galaxies counted to fainter and fainter limits. If their distribution is uniform, then we would expect the observed number to change as the -1.5 power of the light intensity (neglecting intergalactic absorption and relativistic corrections). But optical counts of faint galaxies are difficult to obtain, because the low surface brightnesses and irregular forms of these objects make magnitude determinations slow and uncertain. On the other hand, measurements of radio source intensities are fairly straightforward, with little chance of large systematic errors. Hence, radio sources should be better suited than optically observed galaxies are for testing the large-scale distribution of matter in the universe, especially as they can be detected to presumably much greater distances.

Dr. Ryle had first to show that the great majority of his sources are remote objects. If they were in the extended halo of our galaxy, the off-center position of the sun would produce an unsymmetrical distribution over the sky, but this was not observed. If they were nearby Milky Way objects concentrated near its central plane, they would give a far brighter radio Milky Way than is observed. Dr. Ryle concluded that except in low galactic latitudes only a few per cent of the observed sources

(Continued on page 268)

Measuring Double Stars with a Filar Micrometer

CHARLES E. WORLEY, *Lick Observatory, University of California*

THE AMATEUR who has acquired a filar micrometer has open to him a boundless field of interesting observational work in measuring double stars. This telescope accessory, whose construction was described on page 140 of the September issue, contains two fine parallel wires. Their distance apart can be varied by turning a precision screw, to permit measuring the angular separation between a double star's components. In addition, the direction of the wires is read from a position-angle circle, so they may be set to indicate the direction on the sky of the line joining the two stars.

As was mentioned in that article, the telescope should have excellent optics, and a sturdy, accurately aligned equatorial mounting with a clock drive is essential. For systematic double star work, a refractor of 8-inch aperture or larger is a very effective instrument. The value of such observing was described in my first article, August issue, page 73.

The observer must calibrate the micrometer before measures of double stars can be made. First, he finds the north point on the position-angle circle; this zero point has to be determined independently each night before he begins his observations. Second, he must find the number of seconds of arc corresponding to one revolution of the micrometer screw. Once it has been accurately determined, this value remains practically constant.

To find the north point of the position circle, proceed as follows. Using a low magnification, set the telescope on a star near the celestial equator and in the meridian. Let the star trail along the fixed wire, correcting any deviations by rotating the micrometer box and adjusting the tangent screw. When the star trails accurately, the wire is pointing east-west. Then, 90° added to (or subtracted from) the position-circle reading gives the north point.

As an example, suppose that the circle reading is 98°.6 when a star trails along the fixed wire. Then 8°.6 is the north point on the circle. Later that night, in measuring the position angle of a double star, the circle reading is, say, 245°.4. The true position angle is therefore 245°.4 − 8°.6 = 236°.8.

The determination of R, the value of one revolution of the micrometer screw, is more complicated. We shall use the method of directly measuring the difference of declination between two stars whose positions are accurately known. R is found by dividing the number of screw revolutions into the known difference in declination. This method gives R with sufficient precision for reducing measures of close double stars, since the accidental and systematic errors of a measured separation are quite large even under the best conditions.

Tabulated below are three pairs of stars conveniently distributed around the sky. The bright pair 27 and 28 Tauri, Atlas and Pleione in the Pleiades, will probably prove best to use. In principle, the star positions should be individually corrected to the date of the observation by taking into account precession, aberration, and proper motion. By omitting these corrections, simplicity is gained with little loss in accuracy. Though the star positions in the table are for the date 1962.0, the *differences* in declination will remain practically unchanged for many years. A further correction for atmospheric refraction should be made, but if the pairs are observed when within 30 degrees of the zenith, the differential refraction is very small and may be safely neglected.

The measurements to determine R should be made when the star pair is near the meridian. First, using a low power, carefully find the zero of the position-angle circle, and clamp the wires in the east-west direction. Then, with a higher power, make repeated measurements of the separation in declination of the star pair, by the technique described below. Measure the pair in the north-to-south direction, then rotate the micrometer 180° and measure from south to north.

If the field of view is too small to encompass both stars simultaneously, one or more intermediate stars may be used. These should lie on nearly the same line as the star pair, but their exact positions are immaterial.

The accompanying observations of the pair 27 and 28 Tauri will serve as an example:

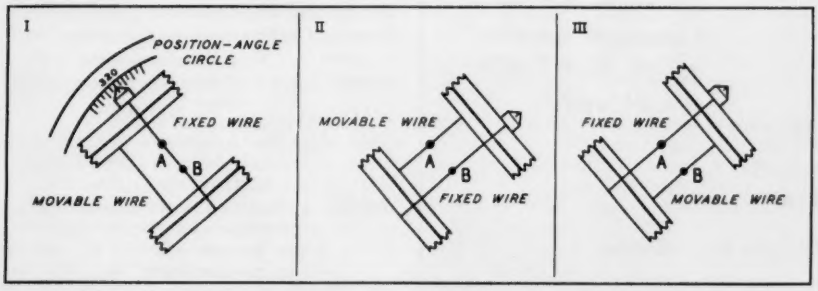
N-S	Revolutions
28 Tau to intermediate star	10.46
Intermediate star to 27 Tau	14.56
Sum	25.02
S-N	
27 Tau to intermediate star	14.53
Intermediate star to 28 Tau	10.47
Sum	25.00
Average	25.01

Then R = 301″.0/25.01 = 12″.04 per revolution of the screw.

Such determinations of R should be repeated on a number of nights, and the mean used in the reduction of double star measures.

We finally come to the problem of making an actual measurement of a double star. Observations should be attempted only on nights of good seeing, and the highest power that the seeing will permit should always be employed.

Star Pair	*Magnitude*	*Right Ascension* h m s	*Declination* ° ′ ″	*Dec. Diff.* ″
27 Tauri	4.0	3 46 53.8	+23 56 19.9	
28 Tauri	5.2	3 46 55.2	+24 01 20.9	301.0
BD +34°2332	5.4	12 31 41.7	+33 35 23.4	
BD +34°2333	6.4	12 31 55.3	+33 43 35.5	492.1
BD +23°3843	7.1	19 55 00.5	+23 47 09.7	
BD +23°3845	6.7	19 55 12.2	+23 40 24.7	405.0



In I, at the left, a setting for position angle is shown, with the fixed wire bisecting the stars. Two settings are needed for the separation, the difference between II and III giving twice its value, as the movable wire is shifted from one side of the fixed wire to the other.

The diagram labeled **I** shows the method of measuring the position angle of the double. With the aid of the tangent screw and position-angle pinion, the fixed wire is set across the star images **A** and **B** as accurately as possible. During this operation, the line joining the observer's eyes should always be held either parallel or perpendicular to the line joining the stars. When satisfied that the wire is properly oriented, read the position circle and give the micrometer box an arbitrary turn. This helps insure that successive settings are independent of one another. It is de-

sirable to make four settings for position angle.

To measure the separation, rotate the micrometer box by 90° and clamp it. Two or three settings are made with the wires in the position shown in the diagram that is labeled **II**, followed by an equal number as shown in diagram **III**. The interchange of wires eliminates the need to find the coincidence reading of the two wires, and gives the double distance. Since we know R, we find the separation, ρ, of the pair, in seconds of arc, from $\rho = \frac{1}{2}R$ (*second reading — first reading*). Note that separation measures are always made in the order of increasing readings of the screw, in order to eliminate backlash. In making such distance measures, you can lessen bias by taking your eye from the ocular and randomly turning the micrometer screw between settings.

An example of an actual observation made by the author with the Lick Observatory 12-inch refractor is shown below. It was made on the double Σ1932, on May 27, 1960. The practice of double star observers is to report the date of every measure, dividing the year decimally, 1960.402 in this case. To reduce accidental errors, the double star should be measured on three or more nights in the same season, and an average obtained.

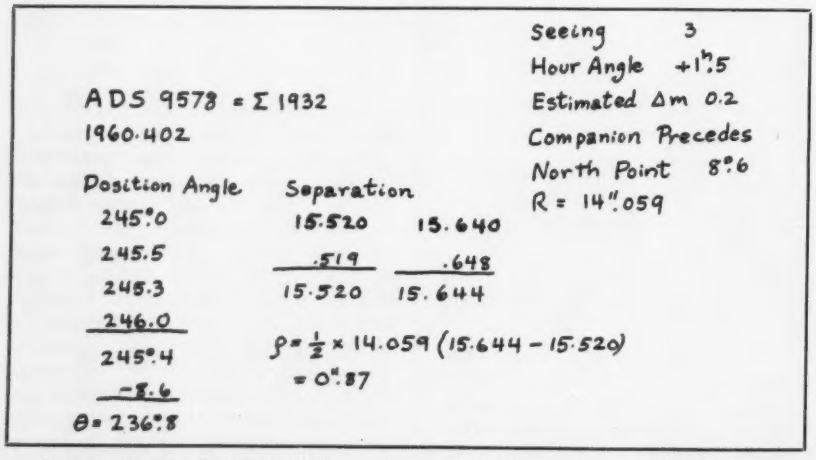
In this article, only a brief outline of techniques can be given. The reader will find much information on micrometers and observing methods in R. G. Aitken's book, *The Binary Stars* (1935). Also worth consulting are J. B. Sidgwick's *Observational Astronomy for Amateurs* (1955) and *Amateur Astronomer's Handbook* (1955), as well as the chapter on micrometers in *Amateur Telescope Making — Book II* (1949). See also an article by W. H. van den Bos, "Some Hints for Double-Star Observers and Orbit Computers," in *Publications* of the Astronomical Society of the Pacific, *70*, 160, 1958.

In the following list are 97 interesting double stars suitable for micrometric observations with 6-inch to 12-inch telescopes. Current position angles and separations are listed both as an aid in identification and to help the casual observer test the resolving power of his telescope.

All of the pairs listed here show appreciable orbital motion. In the last column, the period of revolution is given when known. Uncertain values are marked with a colon (:), very uncertain ones with a double colon (::). Asterisks indicate notes.

Some Interesting Doubles for Amateur Observation

ADS	*Name*	*R.A. (1950)* h m	*Dec.* ° ′	*Magnitudes*	*P.A.* °	*Sep'n.* ″	*Period (years)*
61	Σ 3062	0 03.5	+58 09	6.5-7.3	245	1.4	107
434	λ Cas	0 29.0	+54 15	5.4-5.7	175	0.6	
588	OΣ 18	0 39.8	+03 54	7.8-9.4	185	1.5	500:
746	OΣ 20	0 51.9	+18 55	6.2-6.9	250	0.5	210
755	36 And	0 52.3	+23 22	6.0-6.4	185	0.7	165
940	φ And	1 06.6	+46 59	4.5-5.9	155	0.4	370:
1254	Σ 138	1 33.4	+07 23	7.6-7.6	50	1.6	
1538	Σ 186	1 53.3	+01 36	6.8-6.8	50	1.4	160
1709	Σ 228	2 10.8	+47 15	6.6-7.1	250	0.8	144
1860*	ι Cas	2 24.9	+67 11	4.7-6.9	235	2.4	900::
2004	Σ 285	2 35.9	+33 12	7.5-8.2	165	1.9	
2257	ε Ari	2 56.4	+21 08	5.2-5.6	205	1.6	
2377	OΣ 50	3 07.6	+71 22	8.4-8.4	180	1.4	
2416	Σ 367	3 11.5	+00 33	8.8-8.8	155	0.9	900::
2446	OΣ 53	3 14.5	+38 27	7.8-8.3	280	0.8	118
2612	Σ 400	3 30.9	+59 52	6.8-7.8	250	0.6	250:
2616	Σ 412	3 31.5	+24 18	6.6-6.7	15	0.5	600:
2668	Σ 425	3 37.0	+33 57	7.5-7.7	80	2.0	
2799	OΣ 65	3 47.3	+25 26	6.0-6.4	200	0.6	62
2963	Σ 460	4 01.4	+80 34	5.7-6.4	95	0.9	450:
2995	OΣ 531	4 04.2	+37 57	7.3-8.8	35	1.2	700::
3082	OΣ 77	4 12.8	+31 34	8.0-8.1	260	0.7	200
3093*	o^2 Eri	4 13.2	−07 41	9.6-11.1	350	7.5	248
3169*	OΣ 82	4 19.9	+14 56	7.4-8.6	15	1.4	200:
3330	Σ 567	4 33.8	+19 24	8.9-9.4	335	2.0	
3390	Σ 577	4 38.8	+37 25	8.5-8.6	35	1.4	
3672	OΣ 95	5 02.6	+19 44	6.9-7.6	310	1.1	
3711	OΣ 98	5 05.2	+08 26	5.9-6.6	70	0.8	163
3956	Σ 677	5 20.0	+63 21	7.9-8.2	185	1.0	400:
4208	Σ 749	5 34.0	+26 54	6.4-6.5	155	1.1	
4472	β 1053	5 50.1	+37 20	6.9-8.5	350	1.5	
5197	Σ 932	6 31.5	+14 48	8.1-8.3	320	1.8	
5400*	Σ 948	6 41.8	+59 30	5.4-6.0	90	1.7	700::
5586	OΣ 159	6 53.0	+58 29	4.7-6.0	35	0.9	
5871	Σ 1037	7 09.7	+27 19	7.2-7.2	330	1.2	116
5958	OΣ 170	7 14.9	+09 23	7.6-7.9	95	1.4	
6117	Σ 1093	7 26.5	+50 05	8.8-8.8	175	0.9	
6175*	α Gem	7 31.4	+32 00	2.0-2.8	160	2.2	500:
6263	Σ 1126	7 37.5	+05 21	6.4-6.8	160	1.1	
6623	Σ 1187	8 06.4	+32 22	7.2-8.0	30	2.6	
6650*	ζ Cnc	8 09.3	+17 48	6.9-7.2	0	1.1	60
6993*	ε Hyd	8 44.2	+06 36	3.7-7.1	270	3.1	
7071	Σ 1291	8 51.2	+30 46	6.3-6.5	135	1.5	
7203	σ^2 UMa	9 06.0	+67 20	4.8-8.3	20	2.4	700::
7307	Σ 1338	9 17.9	+38 24	6.5-6.7	225	1.2	300:
7704	OΣ 215	10 13.6	+17 59	7.2-7.5	190	1.3	500:



An example of a double star observation made by the author on May 27, 1960.

*ADS	NOTES
1860	The A component is an astrometric binary. There is another companion at 7″, mag. 7.1.
3093BC	This pair shares common proper motion with the 4.5-mag. star o Eridani, which is 82″ distant in position angle 105°. The close pair consists of a white dwarf and a red dwarf. The white dwarf is probably the representative of its class that is most easily seen in a small telescope.

ADS	Name	R.A. (1950) h m	Dec. ° ′	Magnitudes	P.A. °	Sep'n. ″	Period (years)
7724	γ Leo	10 17.2	+20 06	2.1-3.4	120	4.3	660::
7730*	Σ 1426	10 17.9	+06 41	8.5-8.9	300	0.9	
7929	OΣ 229	10 45.2	+41 22	7.5-7.8	295	0.8	
8119*	ξ UMa	11 15.6	+31 49	4.3-4.8	145	2.4	60
8148	ι Leo	11 21.3	+10 48	4.0-6.7	205	1.0	200:
8197	OΣ 235	11 29.5	+61 22	5.8-7.1	70	1.0	73
8539	Σ 1639	12 21.9	+25 52	6.7-7.8	330	1.3	700:
8575	Σ 1647	12 28.0	+10 00	8.6-8.8	235	1.3	
8630	γ Vir	12 39.1	−01 11	3.5-3.5	310	5.0	172
8695*	Σ 1687	12 50.8	+21 31	5.2-7.4	140	1.0	700::
8708	OΣ 256	12 53.9	−00 41	7.3-7.4	90	0.9	
8974	Σ 1768	13 35.2	+36 33	5.1-7.0	110	1.7	240
9031	Σ 1785	13 46.8	+27 14	7.6-8.0	140	2.9	155
9167	Σ 1820	14 11.4	+55 33	8.8-9.1	100	2.4	
9182	Σ 1819	14 12.8	+03 22	7.8-7.9	280	0.9	360:
9229	Σ 1834	14 18.5	+48 44	7.9-8.1	100	1.2	320
9343	ζ Boo	14 38.8	+13 57	4.5-4.5	310	1.1	123
9418	OΣ 287	14 49.6	+45 08	8.4-8.6	160	1.2	
9494*	44 Boo	15 02.2	+47 51	5.2-var.	275	0.8	254
9578	Σ 1932	15 16.2	+27 01	7.3-7.3	235	0.9	180:
9626*	μ Boo	15 22.6	+37 31	7.0-7.6	25	1.9	260
9716	OΣ 298	15 34.3	+39 58	7.5-7.6	185	1.2	56
9909*	ξ Sco	16 01.6	−11 14	4.9-4.9	350	0.8	46
10075	Σ 2052	16 26.7	+18 31	7.7-7.8	155	0.9	225:
10087*	λ Oph	16 28.4	+02 06	4.2-5.3	345	0.9	130
10157	ζ Her	16 39.4	+31 41	2.9-5.5	55	1.3	34
10235	Σ 2107	16 49.8	+28 45	6.8-8.2	75	1.2	260
10279*	Σ 2118	16 56.2	+65 07	7.1-7.3	70	1.1	700::
10345*	μ Dra	17 04.3	+54 32	5.8-5.8	70	2.0	1,500::
10728	Σ 2218	17 40.0	+63 42	7.2-8.2	330	1.8	
11005*	τ Oph	18 00.4	−08 11	5.2-5.8	270	2.0	280
11046*	70 Oph	18 02.9	+02 32	4.2-6.0	90	4.2	88
11111	73 Oph	18 07.1	+03 59	6.1-7.0	30	0.4	300:
11334	Σ 2315	18 23.0	+27 22	6.6-7.6	140	0.6	800:
11483	OΣ 358	18 33.6	+16 56	6.8-7.0	170	1.9	290
11640*	Σ 2375	18 43.0	+05 27	6.3-6.7	115	2.5	
11871	β 648	18 55.2	+32 50	5.4-7.5	230	1.3	61
12447	Σ 2525	19 24.5	+27 13	8.4-8.7	295	1.7	500:
12880	δ Cyg	19 43.4	+45 00	2.9-6.3	245	2.2	500:
12889*	Σ 2576	19 43.6	+33 30	8.3-8.4	25	1.3	240
13723	OΣ 406	20 18.2	+45 12	7.4-8.2	125	0.5	96
14296*	λ Cyg	20 45.5	+36 18	4.8-6.0	25	0.8	400:
14360	4 Aqr	20 48.8	−05 49	6.4-7.2	0	1.0	150
14499*	ε Equ	20 56.6	+04 06	5.9-6.2	285	0.9	101
15270	μ Cyg	21 41.9	+28 31	4.7-6.0	285	1.5	450:
15971*	ζ Aqr	22 26.2	−00 17	4.3-4.5	255	1.8	600:
15988	37 Peg	22 27.4	+04 11	5.8-7.0	115	1.1	150
16057	Σ 2924	22 31.6	+69 39	6.6-7.1	75	0.5	
16428	52 Peg	22 56.7	+11 28	6.1-7.3	270	0.8	290:
16665	β 80	23 16.3	+05 08	8.5-9.1	290	1.3	92
16836	72 Peg	23 31.5	+31 03	5.9-6.0	240	0.5	220:
17149	Σ 3050	23 56.9	+33 27	6.5-6.7	275	1.5	

3169 The A component is a spectroscopic binary with a period of four days.

5400 The 7.4-mag. star at 8″ is physically associated.

6175 Castor is a remarkable multiple system. Both of the bright components are spectroscopic binaries. Castor C, at a distance of 72″ in position angle 165°, is the well-known eclipsing binary YY Geminorum, with a period of 0.81 day.

6650AB The C component (mag. 6.0, 6″) is physical and is an unresolved astrometric binary.

6993AB-C The A component is a very close visual binary (0″.2). C is a spectroscopic binary of period 9.9 days. There is a fifth physical component at 19″ of mag. 12.5.

7730 The C component (mag. 9, 8″) is physical.

8119 A is both an astrometric and spectroscopic binary. B is also a spectroscopic binary, so the system has four components.

8695 A third star at 29″ separation is physical.

9494 The B component is an eclipsing binary.

9626BC A (mag. 4.5, 108″) is physical.

9909AB C (mag. 7.2, 7″) is physical. ADS 9910, at a distance of 281″, shares a common proper motion, so the system contains five stars.

10087 A third star at 120″ shares in the proper motion.

10279 One component is a spectroscopic binary.

10345 C (mag. 13, 14″) is physical. In addition, one of the bright components may be an astrometric binary.

11005 The brighter component is a spectroscopic binary.

11046 70 Ophiuchi is a famous binary. Both position angle and separation are now decreasing at a fairly rapid rate.

11640 W. S. Finsen recently found both components to be very close pairs. At the time of his discovery, the pairs had nearly identical position angles and separations, and he has suggested that they be named "Tweedledee" and "Tweedledum"!

12889 This pair may have a common proper motion with ADS 12913, which is at a distance of 808″.

14296 The brighter component is a spectroscopic binary.

14499 A visual triple. The third star is 11″ distant and of 7th magnitude.

15971 The fainter component is an unresolved astrometric binary with a period of about 26 years.

QUESTIONS... FROM THE S+T MAILBAG

Q. Which are the five largest reflecting telescopes now in use?

A. The list is headed by the 200-inch f/3.3 Hale reflector at Palomar Observatory. Next come the 120-inch f/5 of Lick Observatory; the 102-inch f/3.8 of the Crimean Astrophysical Observatory in the U. S. S. R.; the 100-inch f/5 at Mount Wilson; and the 82-inch f/4 reflector of McDonald Observatory. In each case, the listed focal ratio is that for the Newtonian or for the prime focus.

Q. When is the next total eclipse of the moon?

A. On December 30, 1963. It will be visible from North America.

Q. Which comet has the shortest known orbital period?

A. Comet Wilson-Harrington 1949 III may hold the record with 2.31 years, but it has not been observed on any subsequent return, and its orbit is very uncertain. Apart from that object, Comet Encke has the shortest known period, 3.30 years.

Q. When will the next transit of Mercury occur?

A. Mercury will pass across the sun's disk on May 9, 1970.

Q. Have weather satellites been of practical use to forecasters?

A. Yes. One outstanding example was the discovery of hurricane Esther on September 10th this year, shortly after it was spawned in the Atlantic Ocean. Without the pictures transmitted to earth by Tiros III, the storm might have remained undetected for several days.

OBSERVING THE SATELLITES

New Ground-Support Facilities

THE immense effort that the National Aeronautics and Space Administration is devoting to the Saturn and other huge-booster programs is evidenced by the scale of their ground-support facilities. A Saturn launching site at Cape Canaveral, other installations along the adjacent Florida coast, an ordnance plant near New Orleans, Louisiana, and a laboratory to be built at Houston, Texas, are all part of the effort to reach the moon.

As told on page 85 of Sky and Telescope for August, 1960, the Saturn is a monster 5,000-ton three-stage rocket, which will stand about 185 feet high on its launching pad. By 1963 or 1964, it will be able to put some 9,000 pounds into interplanetary space.

Now being readied for the Saturn rocket at Canaveral is Launch Complex 34, a 45-acre, $43,000,000 installation. Its dominant feature is a service gantry 310 feet high weighing 2,800 tons. Costing $4,000,000, it is probably the world's largest structure on wheels. Its design posed novel and complex engineering problems.

For example, while anchored to its piers, the structure must withstand hurricane winds of 125 miles per hour, and it must remain accurately level as it moves along its rails. The loads on all 12 wheels in the railroad trucks at each corner are equalized through manifold-connected hydraulic pistons, so that no wheel is overloaded. The corners are kept level by arranging for the same volume of hydraulic fluid in each corner's manifold.

This gantry will be used to erect the rocket on the 27-foot-high launch pedestal near the center of the launch pad, which is 320 feet in diameter. The foundation for the four-columned pedestal required some 4,400 cubic yards of concrete and 580 tons of steel. The pedestal was designed to allow a 60-ton steel flame deflector to be wheeled into position, for bouncing the roaring flame plume (5,000° Fahrenheit) horizontally in two opposite directions.

At a considerable distance from the pad is a spacious blockhouse, whose walls are 12 feet thick and capable of withstanding blast pressures exceeding 150 tons per square inch. Its door alone weighs 23 tons. An "automatic ground control station" serves as a distribution center for measurement, checkout, and control equipment, as well as for electric power.

Already installed are two 30,000-gallon storage tanks for the Saturn's RP-1 fuel (a modified kerosene), and two reservoirs for liquid oxygen. Pumps can transfer the full quota of each of these necessities to the booster in only 40 minutes, or more quickly if necessary.

Nearby is a group of high-pressure tanks containing helium and nitrogen at 6,000 pounds per square inch. When liquid oxygen is aboard the booster, it tends to stratify in the columnar tanks; bubbling helium through the liquid stirs it and keeps its temperature uniform. Liquid nitrogen is used for purging tanks and compartments, and for operating pressure-driven components.

Water is piped throughout the area for fire protection. To separate any fuel that is washed down with the water, a skimming basin is provided.

The first Saturn C-1 booster, the SA-1, was brought to Cape Canaveral from Huntsville, Alabama. During most of its trip it traveled aboard a "floating warehouse" naval barge, after a short portage necessitated by a collapsed dam on the Tennessee River. The SA-1 has been fitted with dummy second and third stages for a test flight to about 100 miles altitude, reaching a few hundred miles down range. The main purpose of this trial will be to test the simultaneous use

This first Saturn rocket, equipped with dummy second and third stages, is to make a 200-mile trip down the Atlantic missile range. Around the booster is draped a rain cover. All photographs in this department are courtesy of the National Aeronautics and Space Administration.

Leading to the Saturn launching pad (foreground) are control and fuel lines from well-protected installations. Counterclockwise from the 28-story-tall gantry at the right are the blockhouse (pictured below) and the spherical 43-foot liquid-oxygen tank. The latter is connected to the launching pad by a six-inch pipeline 650 feet long. At the extreme left are the two fuel tanks for kerosene. At bottom center is the rectangular skimming basin, 180 feet long. The gantry is in its safety position; its rails rest on two mammoth steel beams, eight feet deep, 10 feet wide, and 538 feet long.

of eight rocket engines. In the SA-1 experiment, the feed of propellants, structural loading, operation of launching equipment, and a score of other problems will be carefully studied.

A second-generation rocket, the C-2, is to have considerably more power than the C-1 version. Complex 37, for launching either type, will soon be under construction at Cape Canaveral. Probably it will need even more concrete than the 50,000 tons used for Launch Complex 34.

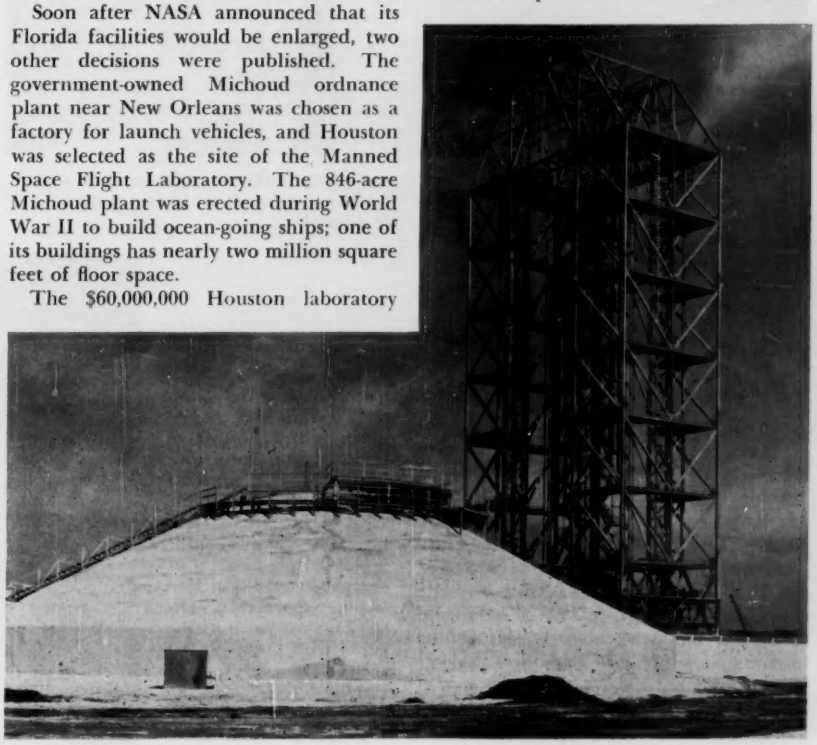
When development of Saturn is sufficiently advanced, it will be used to test-fly the Apollo spacecraft, whose actual launchings for manned lunar exploration will require a much larger booster, presently called the Nova. Few details of the plans for the latter have been decided, but it is already clear that it must provide some 12 to 20 million pounds of thrust.

The tremendous noise level that will accompany blastoff of such a rocket — about 120 decibels at a distance of seven miles from the pad — is actually destructive to many types of structures. Thus a safety zone about 10 miles deep, from which the public is excluded, must surround the firing site. It is also required by the hazards of accidental explosions. There is not room enough at Cape Canaveral, so NASA has begun acquiring about 80,000 acres of adjacent property, at a cost of around $60,000,000, for the Apollo launching site.

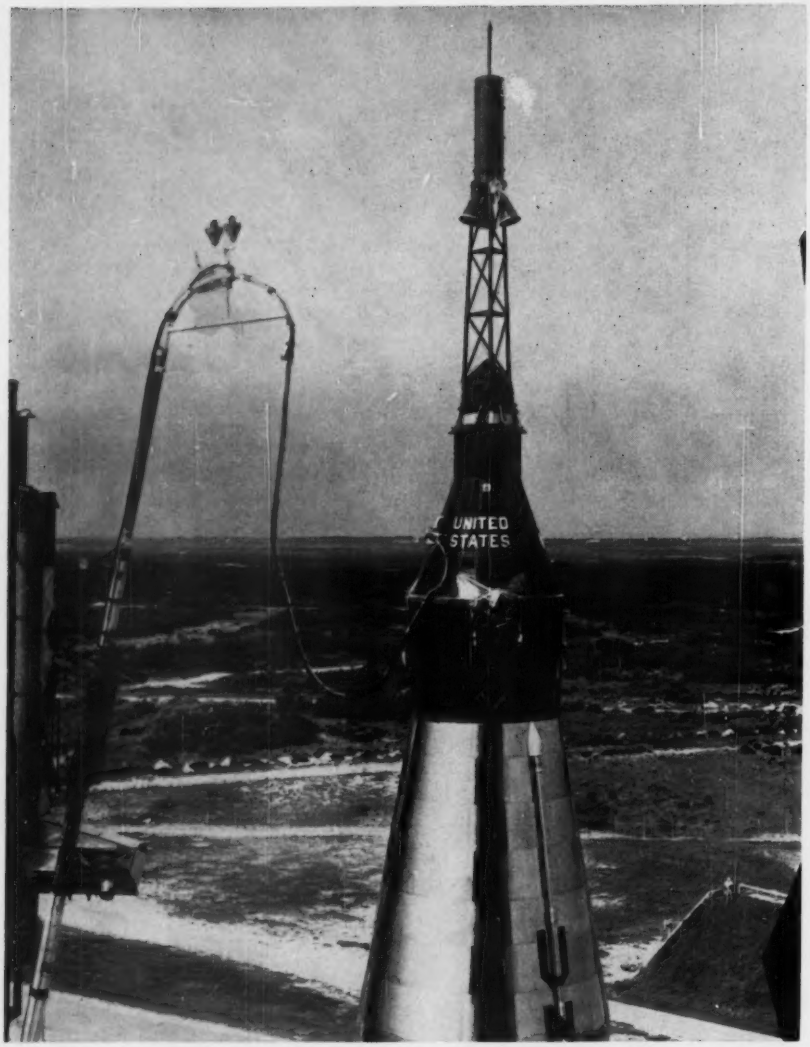
Six other areas were considered for this purpose, but the Canaveral region permits eastward launchings (thereby utilizing the earth's rotation) over the ocean. In addition, water transport is possible, and existing installations may be used. The cost of developing the site has been estimated at about 885 million dollars.

Soon after NASA announced that its Florida facilities would be enlarged, two other decisions were published. The government-owned Michoud ordnance plant near New Orleans was chosen as a factory for launch vehicles, and Houston was selected as the site of the Manned Space Flight Laboratory. The 846-acre Michoud plant was erected during World War II to build ocean-going ships; one of its buildings has nearly two million square feet of floor space.

The $60,000,000 Houston laboratory will be located on 1,000 acres of land made available to the government by Rice University. It is intended to be the command headquarters for the manned lunar



Saturn's service tower dwarfs the Complex 34 blockhouse, itself some 40 feet high and containing 12,500 square feet of floor space protected by concrete and an earth layer seven feet deep in its thinnest part. A roofed cableway (see picture above) runs from the blockhouse to the launching pad.



This Mercury-Atlas-4 capsule, veteran of one firing, is shown prior to its second launching and recovery on September 13th. The escape tower, 16 feet high, was jettisoned after takeoff.

mission as well as subsequent manned spaceflight projects. It will be the center for designing and developing the spacecraft for Project Apollo and for training its crew.

Unmanned Mercury Orbit

AS A CHECK of the Mercury system for orbiting an astronaut, on September 13th an automatically controlled capsule made one revolution around the earth and was recovered from the Atlantic Ocean 161 miles east of Bermuda. Once before, this same capsule had been picked up from the sea, when on April 25th the range safety officer at Cape Canaveral destroyed the Atlas booster because the programmer in its guidance package failed.

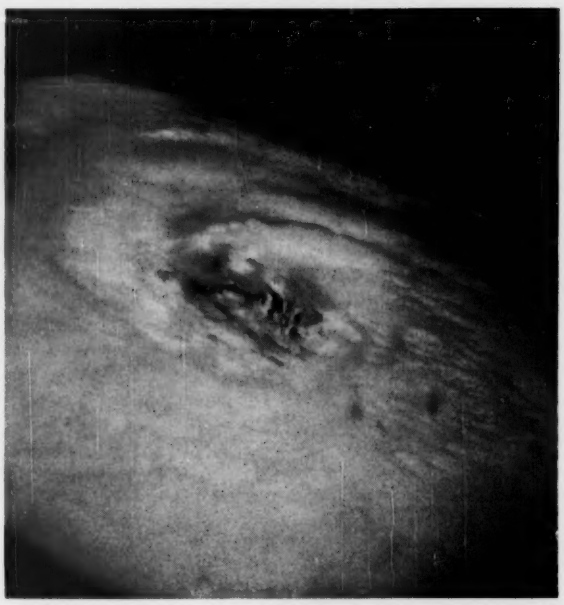
Inspection of a transistorized printed circuit unit used in the present Mercury's guidance system showed that a speck of solder had loosened and caused a short circuit within the sealed package. All such circuits were thereafter inspected by X-ray, and the defect was remedied completely. In this latest Atlas firing, MA-4 attained orbital injection velocity to 0.1 per cent of the intended value, and perigee was within a mile of the planned height.

If a man had been aboard this capsule, he would have survived the voyage, despite minor malfunctions of the equipment. Actually, the capsule carried apparatus to imitate man's need for oxygen, production of carbon dioxide, and liberation of water vapor and heat. The capsule's life-support systems tolerated these burdens, but oxygen consumption was abnormally high. The supply would not have sufficed for three orbital revolutions with a man aboard, and it is suspected that the cabin leaked.

The firing took place at 14:04:16 Universal time on September 13th. The complete spacecraft weighed 3,900 pounds, but its escape tower was jettisoned midway in the 4.93-minute launching sequence, so the package that entered orbit was some 2,700 pounds.

Re-entry was started by a timer after 84.05 minutes in orbit, while the satellite was passing near the tracking station at Guaymas, Mexico. After the retrorockets fired, the incoming trajectory was only inclined some two degrees below the horizontal, so as to spread the work of slowing the vehicle over a long path. The maximum deceleration by the atmosphere during re-entry was thus held to only about 7.8*g*, but at the price of prolonged high temperature. In all, some seven minutes of temperature around 2,000° Fahrenheit were borne by the heat shield as the craft fell from 50 to 10 miles above the earth.

The hot shield and later the parachutes were jettisoned, the capsule weighing about 2,200 pounds at splashdown. The destroyer U. S. S. *Decatur* hoisted it aboard after 81 minutes in the Atlantic, three



During the capsule's 1¾-hour flight, approximately 360 color 70-mm. photographs of the earth were taken. Twelve minutes after launching from Cape Canaveral the camera caught this view of hurricane Debbie. The storm's center lay 100 miles north of the projected flight line of the spacecraft. On the horizon, beyond the cloud whirlpool, may be seen part of the sea. Debbie later crossed the Atlantic and battered Northern Ireland.

hours and 10 minutes from the initial launching.

This capsule lacked a landing bag and used a screw-down hatch. A quick-release hatch, of the kind that unexpectedly led to the loss of the entire capsule after Virgil Grissom's suborbital ride on July 21st, is to be tested further in unmanned orbital flights.

All 24 letters of the Greek alphabet had been assigned this year before the MA-4 shot was made. Thus the capsule is designated 1961αα1, and the Atlas booster, which made about three revolutions before burning in the atmosphere, was named 1961αα2 by the Space Detection and Tracking Network of the Air Force. For the empty 7,400-pound Atlas, the network gives an initial orbital period of 87.3 minutes, inclination 32.85 degrees, and a nearly circular orbit 93 miles high at the equator. NASA's data for the capsule give its perigee as 99.25 miles, apogee 158.6.

Three Discoverer Satellites

DISCOVERERS 29, 30, and 31 have been successfully sent into orbit from Vandenberg Air Force Base, California, and re-entry capsules from two of them retrieved, as part of the U. S. Air Force program for improving space technology.

The three launchings were made at about 20:01 Universal time August 30th, 19:59 September 12th, and 21:00 September 17th, respectively, for satellites 1961ψ, 1961ω1 (and other components), and 1961αβ. The initial periods of these three Agena-B spacecraft were 91.6, 92.4, and 91.0 minutes, and their respective orbital inclinations 82.1, 82.5, and 82.7 degrees. Good progress in controlling orbital characteristics is indicated by the small dispersion in these figures, much less than the average scatter for the Discoverer series as a whole.

A variety of biological specimens was exposed to the environment of space while carried for 33 trips around the earth in the Discoverer-29 capsule, which was retrieved from the sea. After a similar period in orbit, the payload of 30 was caught in mid-air, for the first time by a relatively fast turboprop C-130. The capsule of 31, however, failed to separate from the Agena.

Early on September 10th, Discoverer 29 re-entered the atmosphere. Two metal objects that went into orbit with 30 were designated 1961ω2 and 1961ω3; they reentered on September 19th and 24th, respectively.

Every three weeks or so, the Air Force will launch another satellite in this series, largely to recover specimens and to improve techniques. However, a long-standing plan to launch a monkey in one of the 300-pound capsules has recently been abandoned.

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NEWS NOTES

ORIGIN OF PLANETARY MATERIAL

Many modern theories of the solar system's origin begin with a disk of gas and dust surrounding the sun, and proceed to the formation of the planets from such a disk. F. Hoyle and other astronomers have suggested several ways in which a circumsolar nebula could have been born. Now R. A. Lyttleton of Cambridge University, England, proposes that the sun captured interstellar gas and dust, which gave rise to a suitable planet-forming disk.

The English mathematician has considered the accretion of matter by the sun as it travels through an interstellar cloud of density 10^{-22} gram per cubic centimeter. Such capture would be possible if the velocity of the sun relative to the cloud were as low as 0.2 kilometer per second. At this speed, the sun would move about one light-year in a million years, and would capture a mass equivalent to that of the planetary system. Very little of the accreted material would be added to the body of the sun, almost all going into orbit around it.

Generally speaking, the motions of interstellar clouds relative to the sun are much faster than the 0.2 kilometer per second required by Dr. Lyttleton's hypothesis. Hence only a very small fraction of possible encounters will be suitable. But such clouds are thickly strewn in interstellar space, and Dr. Lyttleton argues that a low-speed encounter could well have occurred during the several billion years the sun may have existed before the formation of its planets.

Among the questions deserving examination is the extent to which turbulent motions inside an interstellar cloud may interfere with the accretion process. The details of Dr. Lyttleton's proposal are published in *Monthly Notices* of the Royal Astronomical Society, *122*, 399, 1961.

CHEMICAL ANALYSIS OF THE LUNAR SURFACE

When an unmanned soft landing on the moon is made, it should permit determining the chemical elements present on the lunar surface. Preparations for such an experiment are being made by three University of California scientists, S. Silver, C. Schrader, and J. Waggoner.

The project involves the bombardment of the surface material with neutrons. Each of the various elements expected to occur on the moon gives off a characteristic form of gamma radiation, when so bombarded. The resulting gamma radiation would be analyzed, and the data telemetered back to Earth. Unless lunar material is much more complex than terrestrial is, it should be possible to identify the elements there with great accuracy.

During the current year, these researchers will use the Cockcroft-Walton accelerator at the Lawrence Radiation Laboratory to make extensive tests of gamma-ray yields from neutrons scattered by laboratory samples that contain the expected lunar elements and mixtures. Being designed is a 35-pound instrument package to be landed on the moon. It is to contain a small particle accelerator, a gamma-ray detector and analyzer, and shielding.

Oil prospectors already employ compact neutron sondes, each having a radioactive source of neutrons and a radiation detector, which can be lowered into deep bore holes. The use of similar equipment for analyses on the moon has been suggested by Jack Green of North American Aviation and Jack Van Lopik of Texas Instruments, who discuss it in *Advances in Space Science and Technology*, Vol. 3.

TEACHING THE EARTH SCIENCES

Underscoring the importance today of astronomy, geology, and meteorology, the Pennsylvania Department of Public Instruction, Box 911, Harrisburg, Pa., has recently published two teacher's guides for earth and space science classes.

Elementary-grade teachers are provided with a 67-page manual containing units on the earth and the universe, at primary and intermediate levels. Actual questions asked by children are listed, with related concepts and suggestions for experiments and activities. The manual contains bibliographies of reading for teacher and student, and a list of films that tells where they may be obtained.

For junior high and high school courses, a 103-page guide suggests a year's program in the earth sciences. Eleven weeks are

IN THE CURRENT JOURNALS

FREEZING NUCLEI, METEORS, AND RAINFALL, by N. H. Fletcher, *Science*, August 11, 1961. "During the past eight years the meteor hypothesis has provided a stimulus for much interesting and valuable work on the origin and properties of natural freezing nuclei in the atmosphere. In many ways the results of this work appear to support the hypothesis [that there is a close connection between the earth's passage through meteor swarms and the whole terrestrial rainfall pattern some 30 days later], but . . . other groups of experiments point towards a terrestrial origin for the nuclei."

STELLAR CONTENT OF GALAXIES, by Halton Arp, *Science*, September 22, 1961. "We must expect in the future, it seems, that wherever we encounter low densities we will encounter stars of low metal content. High-density regions produce stars of high metal content, and therefore the stellar content can be quite different from galaxy [to galaxy], and can even be different from region to region within one extragalactic system."

The growth of the brilliant solar flare of September 28, 1961, which preceded by two days an intense auroral display reported by many American observers (see page 271). The red-light pictures (left to right) were taken at 2:07:10 p.m. Pacific standard time, 2:15:00, and 2:23:20. Photographs courtesy G. E. Moreton, Lockheed Solar Observatory.

devoted to geology, nine to astronomy, nine to meteorology, and three to oceanography. Topics and experiments are given, along with an extended list of references. In the appendix are directions for making and using a cloud chamber, a star finder, and other equipment.

MAJOR SOLAR FLARE

A short-lived brilliant outburst on the sun took place on September 28th, producing a wide variety of terrestrial phenomena. This was a solar flare of importance 3 or 3+, which began at 22:02 Universal time, reached maximum at 22:24, and faded out gradually during the next three hours. It appeared in solar latitude 15° north, and was 29° of longitude east of the sun's central meridian.

These photographs showing the progress of the flare were taken at Lockheed Aircraft Corporation's solar observatory at Los Angeles, California (see page 145 in March, 1961), and have been supplied by G. E. Moreton. The pictures are selected frames from a series taken at 10-second intervals with a coronagraph of 3-inch aperture. This instrument contains a birefringent filter that transmits only a half-angstrom range of wave lengths in the vicinity of the red spectral line of hydrogen, H-alpha.

The first view, at 22:07:10, shows the flare as it was gradually brightening. A large dark filament overlies the plage area. This exposure was made with the filter tuned to a wave length 0.4 angstrom to the blue side of the center of H-alpha, the other two at 0.2 angstrom to the blue.

In the second picture, made at 22:15:00, the large filament is disappearing as the flare develops. Certain parts of the latter occupy the same positions as portions of the pre-existing filament. Such behavior seems to be characteristic of certain types of flares associated with increased cosmic radiation. The third photograph was taken eight minutes later and shows the flare at very nearly its greatest brightness and size. At maximum, it had an area (uncorrected for foreshortening) of 970 millionths of a solar hemisphere.

The September 28th outburst brought into play many solar-terrestrial phenomena. Fortunately, at the time of the flare University of Minnesota balloons were aloft for geophysical observations, and they measured cosmic-ray increases and solar X-rays. During the flare's most rapid brightening, a radio burst from the sun was recorded at Harvard's radio astronomy station near Fort Davis, Texas. Disturbances of the earth's magnetic field took place, a sudden-commencement geomagnetic storm being observed at Manitoba, Canada.

On September 30th, a brilliant aurora borealis was seen from many places in the northeastern United States. Photographs and descriptions of the display appear on page 271 of this issue. This aurora was probably associated with the solar flare two days earlier, as that is about the interval required for fast-moving charged particles sprayed from the sun to reach the earth.

IAU SYMPOSIUM ON GALAXIES

(Continued from page 260)

are situated within the galaxy — the remainder are extragalactic. Several lines of evidence suggest that the total radio emission from a typical remote source is roughly 10^{26} to 10^{27} watts per cycle per second per steradian, comparable to the emission from Cygnus A.

An analysis of the number-flux density relation for sources at galactic latitudes greater than 20 degrees was made, and showed that the numbers changed as the −1.8 power rather than −1.5. This difference indicates a substantial excess of faint sources, and thereby disagrees with current cosmological theories. The explanation might be that the sources (galaxies) had in the past been more intense emitters, either through greater supernova activity or because they had contained more gas, resulting in greater radio emission during collisions.

These first results from the new Cambridge telescope are of such far-reaching implication that testing them in every possible way and extending them to yet fainter and more distant sources will be important tasks for radio astronomers. At some high level of sensitivity, perhaps already reached at Cambridge, the relatively weak radiation of multitudes of stars in our own Milky Way galaxy may be detected, initiating a whole new field of investigation in an already exciting branch of astronomy.

Amateur Astronomers

Louisville's Star Lane Observatory

TWENTY YEARS to plan and construct a 20-inch f/5 reflector and its observatory is considered time well spent by members of the Louisville Astronomical Society. Star Lane Observatory, located on New Cut Road some two miles from our Kentucky city's Iroquois Park, is used extensively by senior and junior amateurs, as well as providing a place for general public instruction in celestial phenomena.

In 1936 a 20-inch Corning mirror blank was purchased for $80. Grinding began during the spring of 1937, in the basement of the old physics building of the University of Louisville. Due to the war, however, society members had to move their operations several times, and final polishing and testing took place at the home of Dr. W. L. Moore, on whose property the observatory is now located. In 1955 the completed mirror was taken to Chicago to be aluminized. Total outlay for the Newtonian instrument and its mounting came to about $325.

The observatory is of fairly simple, inexpensive construction, costing about $625. Concrete blocks form a cylinder 17 feet in diameter, topped by a silo dome modified with a pair of tin snips and a bit of imagination. Two molded aluminum sheets shutter the dome, the lower one rolling along tracks lining the rectangular opening. A motor hauls this sheet up over the top of the dome by means of stainless steel cables, and the upper sheet rides "piggyback" out of the way. This arrangement has proved most satisfactory, and there are no projecting parts or shutters to catch the wind. The dome is easily rotated by a mechanism which turns a track mounted to the dome's lower edge. The track rides on rollers attached to the top of the observatory wall.

Dedication of the facility on September 4, 1955, highlighted the Astronomical League's Middle-East convention that year. Since then, numerous accessories have been added, many made by members of the society. In 1958 a clock drive, electric slow motions, and setting circles were installed. Provision for using the telescope's Cassegrainian focus was made in 1959, and last year a sidereal clock was added to the observatory's equipment.

Harry Haarman, a 17-year-old member of the Louisville Junior Astronomical Society, has constructed an astro-camera which screws into the telescope. The camera's body is of sheet metal, with a focal-plane shutter which can be operated with rubber bands or by hand. A guide telescope, now being completed by Mr Haarman, is an f/40 off-axis system, with a $4\frac{1}{4}$-inch primary and a $3\frac{3}{8}$-inch flat secondary. A 6-inch guiding refractor is also under construction, as well as a photometer.

The 20-inch is perhaps the largest instrument in the world made freely available to juniors. They have achieved excellent results in astrophotography, especially of lunar eclipses and the 1960 transit of Mercury. Under the auspices of the American Association of Variable Star Observers, a regular program of sunspot observing is now being conducted by Dr. Moore.

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Louisville 6, Ky.

+++ Amateur Briefs +++

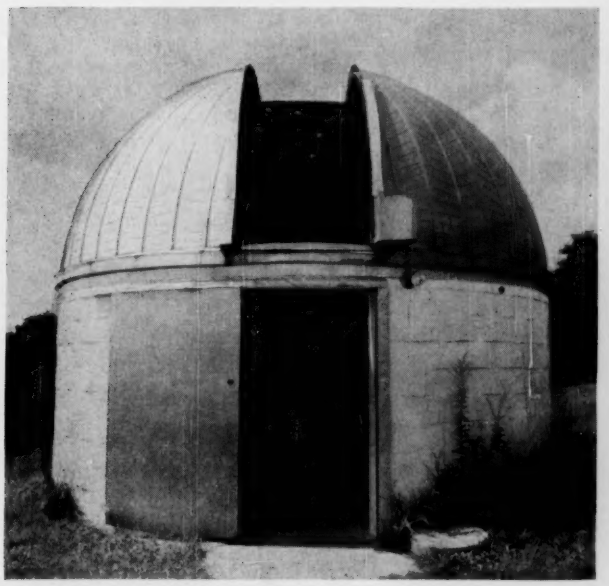
When placed in orbit on August 12, 1960, Echo I was expected to have a lifetime of only three months! The balloon has been very popular with the Montreal Centre of the Royal Astronomical Society of Canada, as indicated by an impressive list of observers during its first year in orbit. V. Williams spotted the satellite 220 times during the first 12 months, and J. Low reported the second largest number of sightings, 83.

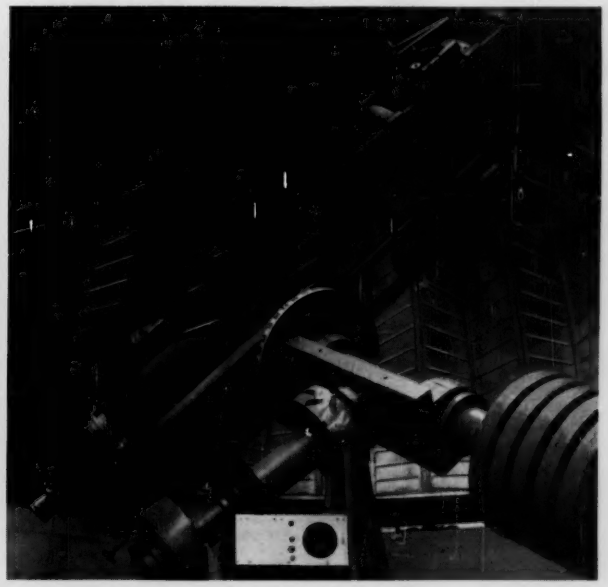
Edward Taylor of the San Francisco Amateur Astronomers writes of the group's September star party at Lick Observatory, 75 miles from the city. Dr. A. E. Whitford, director, welcomed the 80 visitors, who toured the dome of the 120-inch reflector and then looked through the 12- and 36-inch refractors at Jupiter and Saturn. The visitors also brought 17 of their own telescopes, including two 12-inch reflectors.

"Meteors," an astronomical lecture given before the Orion Society of El Paso, was tape recorded, and is now being lent to other groups through Charles W. Isbell, 1519 Golden Hill, El Paso, Tex. The speaker is Dr. Harold S. Slusher, of the department of physics of Texas Western College, and his remarks last about three quarters of an hour. The lecture may be borrowed, or it can be dubbed onto any seven-inch, 1,200-foot reel of tape as a permanent addition to a club's files.

On September 13th a New Jersey junior presented a 15-minute radio talk to the listeners of station WCDN in Camden. Bill McManus' comments on astronomy and the amateur were well received, and he is anticipating giving future programs.

Director Barry L. Fisher of the McKeldin Planetarium, St. John's College, Annapolis, Maryland, has announced that





The Star Lane Observatory of the astronomical society in Louisville, Kentucky, contains a 20-inch Newtonian reflector on a standard German mounting. The instrument was constructed by members of the club. Photographs by John Denham.

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BACK ISSUES for sale: *Sky, Sky and Telescope*, 1936 to date, 50¢ to $1.25 each. Send want lists. Library, Amateur Astronomers Association, 223 W. 79th St., New York 24, N. Y.

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FOR SALE: Complete *Sky and Telescope*, 1946 to date, except for April, 1946, issue. J. A. Kozlarek, Dover Plains, N. Y.

public showings with the Spitz A-2 projector will take place every Saturday evening at 7:00 this winter.

Tourists to the U. S. S. R. might enjoy meeting amateurs in such cities as Moscow, Leningrad, or Smolensk. In his new Russian-language *Amateur Astronomer's Handbook*, P. G. Kulikovsky lists a number of amateur groups and their addresses.

On July 11th G. H. Smith of Salisbury, Southern Rhodesia, observed a twilight occultation of Mercury, using his 6-inch f/10 reflector at 120x. The 1½-day-old moon was barely visible, but Mercury showed a small bright crescent which moved almost tangentially to the moon's southern edge. It rapidly faded from view, except for "a starlike point of light that lingered at the limb for several seconds, the total time for extinction of the planet being about 18 seconds."

Amateur astronomers from Danville, and Chicago, Illinois, and Minneapolis, Minnesota, gathered in mid-August at Indiana Dunes State Park, located along the southern shore of Lake Michigan, for their sixth annual Tremont convention. Observing the Perseids, swimming, hiking, and relaxing on the beach were major activities.

G. B. C.

THIS MONTH'S PROGRAMS

New Orleans, La.: Pontchartrain Astronomy Society, 8 p.m., Tulane University Observatory. November 3, Dr. J. Frazer Thomson, Tulane University, "The Origin of the Solar System."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. November 1, George T. Keene, Eastman Kodak Co., "Astrophotography."

New York, N. Y.: Junior Astronomy Club, 8 p.m., Waverly Building, New York University. November 17, Dr. Sarah Lee Lippincott, Sproul Observatory, "The Nearest Stars."

Pittsburgh, Pa.: Amateur Astronomers Association of Pittsburgh, Allegheny Observatory. November 10, James Mullaney, "Jupiter's Red Spot Revisited."

Shreveport, La.: Shreveport Junior Astronomical Society, 7:30 p.m., Centenary College science hall. November 18, Dr. J. W. Morton, Louisiana Polytechnic Institute, "Eclipses and Occultations."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. November 4, Dr. David Q. Wark, U. S. Weather Bureau, "Looking at the Planet Earth from Space."

CLIFTON, NEW JERSEY

Five high school students have recently organized the Clifton Astronomical Society and are now working to expand the club. Interested amateurs should contact John Ziemba, 144 Piaget Ave., Clifton, N. J.

IOWA STAR PARTY

Publicity by local television stations and newspapers announced the first open star party to be held in northernmost Iowa, and resulted in over 150 persons coming to the Basma Observatory in Buffalo Center on the evening of August 19th.

Refractors from 1½ to six inches in size, and reflectors ranging from three to 10 inches were set up for the event. Most of the instruments were homemade. Visitors were also shown lunar slides.

Astronomy is attracting increasing public interest in our area, and we are looking forward to starting an amateur club.

JIMMY WENTWORTH
Thompson, Iowa

AL REGIONAL CONVENTION

The Astronomical Society of Harrisburg, Pennsylvania, was host for the August 19th convention of the Astronomical League's Middle East Region. Seventy registrants attended the sessions at the Cocoa Inn in Hershey.

Papers were heard on classification of deep-sky objects, the Jovian cloud bands, and stellar spectra taken with a 31-inch reflector. Highlighting the program was the demonstration of a grinding machine and a 6-inch Maksutov telescope constructed with it by Bob Thompson and Don Neidig of Harrisburg.

The 1961-62 officers of the region are: chairman, Antony Doschek, Pittsburgh; vice-chairman, James Mullaney, Pittsburgh; treasurer, Edward Naylor, Harrisburg; and secretary, Emil Volchek, Wilmington, Delaware. The convention passed a resolution requesting the National Aeronautics and Space Administration and other involved government agencies to modify or discontinue those space projects that will interfere with astronomical research or significantly change the aspect of the night sky.

The featured speaker at the banquet was Dr. N. E. Wagman, director of Allegheny Observatory.

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OBSERVER'S PAGE

Universal time (UT) is used unless otherwise noted.

WIDESPREAD NORTHERN LIGHTS ON SEPTEMBER 30TH

OBSERVERS in the northeastern part of the United States were treated to a spectacular aurora on Saturday evening, September 30th. Reports received from amateurs as far south as Delaware and west to Ohio indicate that the bright display covered the entire region. For the more northern observers, the entire sky was aglow with colorful arcs and rays. West of the Great Lakes, however, extensive cloud cover obscured the display in many places.

Two days earlier, an intense solar flare had been observed at Lockheed Solar Observatory (see page 268), and probably was associated with the Saturday northern lights. C. W. Gartlein, who is director of the Auroral Data Center at Ithaca, New York, described this aurora as "one of the largest in recent years." He also noted that disturbances in the earth's magnetic field coincided with the observed brightenings and southward extensions of the auroral storm.

Beginning about 7 p.m. Eastern standard time, a faint greenish glow was sighted by G. Derbenevich, Riverside, Connecticut, who thought at first that it was only some clouds. Pilot R. E. Fried, who was flying toward New York City from Atlanta, Georgia, also thought for a time he was observing clouds, but noticed a strange westward motion of the bright patches. The same drift to the west was described by Dr. Gartlein and by V. Pytko, Hoosick Falls, New York.

Others who spotted the activity early that evening and watched it grow were: K. J. Delano, Wareham, Massachusetts, who used a green filter to identify the early forms as auroral; R. Rudnicki and T. Lada, who observed together at New Britain, Connecticut; and R. L. Stahl, Johnstown, Pennsylvania, who reported that all but the brightest stars were masked by auroral light at the peak of the display.

For some watchers it was a particularly colorful aurora. D. Price, Westerville, Ohio, reported faint green, with bright

John T. Hopf's picture of the sky over Newport, Rhode Island, about 10 p.m. Eastern standard time, September 30th, shows Mizar and Alcor near bottom center, Thuban to the right above center, and Little Dipper stars at the top.

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Above: Looking eastward from Pittsburgh, Pennsylvania, at 9:45 p.m. EST, W. A. Feibelman recorded a broad auroral glow, with some rayed structure.

Left: These streamers, photographed by Mr. Hopf, accompanied the coronal form that was seen at Newport, Rhode Island, at 10 p.m. EST. The stars of Perseus dominate the picture, with Algol near top right. Capella, in Auriga, is at left center, near the tree.

red rays reaching their maximum intensity about 9:45 p.m. EST.

In Buffalo, New York, amateur Clark Chapman observed a bright region somewhat south of his zenith. At 9:45 EST a dark center appeared, forming the classical corona. This same feature was also recorded at Dover, Delaware, by R. M. Jepeal.

From Auburn, New York, the aurora appeared as "a huge, finely pleated curtain gently moving in a breeze," according to B. Lewis. The sky was nearly covered by the display as seen by M. C. Kimball, at Dover-Foxcroft, Maine; R. Kolodny, Flushing, New York; and P. L. Dombrowski, New Britain, Connecticut.

After reaching its maximum at about 10 o'clock, the activity rapidly subsided, and soon was considered over by most observers. At Philadelphia, Pennsylvania, however, W. Wisniewski heard about the event on a news broadcast at 2 o'clock in the morning, and went outdoors to see the entire northern sky still covered by a faint greenish glow.

W. A. Feibelman, Pittsburgh, Pennsylvania, also noticed a rebirth of activity, but contrary to his earlier observations, predominant motions were from west to east. According to Dr. Gartlein, motion westward before maximum and eastward after is rather common, but present knowledge is insufficient to explain it.

Bright and extensive colors were reported by R. Stibich, Garfield Heights, Ohio; L. Secretan, Greenbelt, Maryland; H. A. Luft, Bayside, New York; and W. Hladky, Ridgewood, New Jersey.

By October 9th, many letters testifying to the extent of the display had been received. An impressive spectacle was reported by R. W. Crowder and P. Mennemeyer, Neodesha, Kansas; G. Solberg, Las Cruces, New Mexico; R. Schmidt, Winston, New Mexico; W. T. Dixon, Vienna, West Virginia; and G. Bisjak, Jr., Chino Valley, Arizona.

In addition to the illustrations with this summary, good photographs were submitted by R. A. Yajko, Leechburg, Pennsylvania, and D. A. Wentraub, Cranston, Rhode Island; a chart by G. Lovi, Lakewood, New Jersey; and pictures of the sun prior to the aurora by W. R. Winkler, Stratford, Connecticut.

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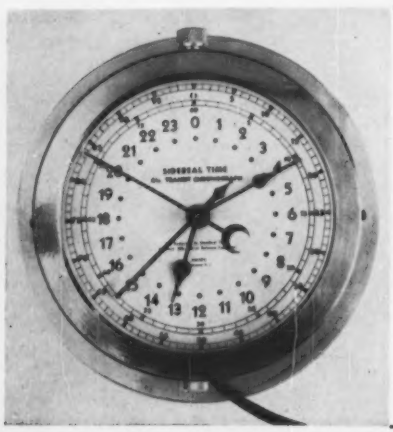

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Sky and TELESCOPE

NOVEMBER, 1961

Occultation Supplement

1962 Predictions for the United States and Canada

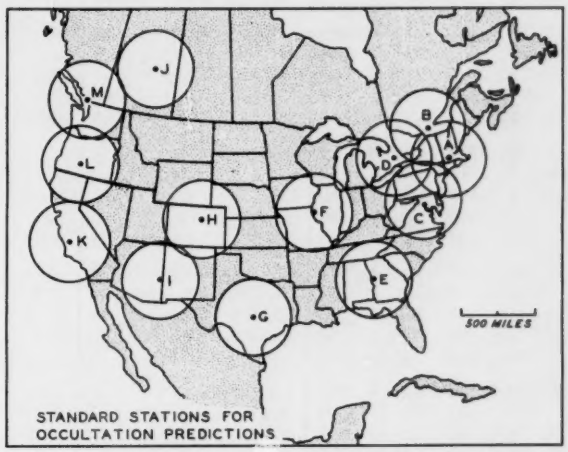
FOR THE THIRD YEAR this supplement is a feature of SKY AND TELESCOPE. Prepared at the Nautical Almanac Office of the Royal Greenwich Observatory under the supervision of Mrs. Flora McBain Sadler, these tables provide occultation predictions for the 13 stations shown on the map. They are named and their positions given in the table headings on the following pages. Station E has been added this year.

The first five columns give the date for each occultation, *Zodiacal Catalogue* number of the star, its magnitude, the phenomenon (*1* = disappearance, *2* = reappearance), and the age of the moon in days. Under each station are given the Universal time of the event, **a** and **b** factors in minutes of time, and the position angle **P** (measured from the north point, eastward around the moon's limb to the point of occurrence of the phenomenon).

In certain cases, predictions have been omitted and letters indicating the reason inserted in their places: *G*, grazing occultation; *H*, below or too near the horizon; *N*, no occultation; *S*, sunlight interferes. Certain other cases where satisfactory observations would be impossible are also omitted.

The **a** and **b** factors are the changes in standard-station predicted times per degree of longitude and latitude, respectively. They enable fairly accurate computation of times for each local station (longitude Lo, latitude L) within 200 or 300 miles of a standard station (longitude LoS, latitude LS). The local-station time is the standard-station time plus the quantity **a**(Lo − LoS) + **b**(L − LS), with due regard being given to the arithmetic signs. The longitudes and latitudes are expressed in degrees.

On the map the standard stations are at the centers of circles of 250-mile radius, and in these areas the **a** and **b** factors should be quite useful. For positions outside the circles an improvement to the predicted times may sometimes be made by applying corrections to **a** and **b** before using them. For directions on computing these corrections and for examples of the use of the occultation tables, see this supplement's last page.



STANDARD STATIONS FOR OCCULTATION PREDICTIONS

Precise timings of occultations are useful amateur work, if recorded to 0.1 second and accurate to within 0.5 second. The only equipment needed besides a small telescope is a stopwatch and a short-wave receiver for WWV or CHU radio time signals. In addition, the observer must know his geographical latitude and longitude, and height above sea level — information readily found from the large-scale topographical survey maps of the U. S. Geological Survey. Detailed information on procedures is given in SKY AND TELESCOPE for December, 1959, page 84.

The world center to which occultation timings are reported is H. M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, Sussex, England.

OCCULTED STARS AND PLANETS

Z. C. No.	Name, B. D. or C. D. No.	Z. C. No.	Name, B. D. or C. D. No.	Z. C. No.	Name, B. D. or C. D. No.	Z. C. No.	Name, B. D. or C. D. No.	Z. C. No.	Name, B. D. or C. D. No.
20	25 B. (Cet)	741	318 B. Tau	1236	ζ Cnc m.	2223	γ Lib	3058	19 Cap
25	−4° 12 Cet	764	104 Tau m.	1241	+18° 1882	2245	190 B. Lib	3086	−18° 5862
62	11 Cet	823	+18° 862	1259	20 Cnc	2247	η Lib	3105	114 E. Cap
66	−2° 69	829	+18° 873	1262	25 Cnc	2280	204 B. Lib	3113	30 Cap
76	14 Cet	832	119 Tau	1275	θ Cnc	2291	49 Lib	3115	31 Cap
83	15 Cet	836	120 Tau	1310	δ Cnc	2341	−17° 4534	3126	ι Cap
150	26 Cet	862	+18° 920	1331	Y Cnc	2390	120 B. (Sco)	3167	136 B. Cap
165	29 Cet	863	127 Tau	1335	+17° 1979	2399	24 (Sco)	3171	γ Cap
170	33 Cet	871	+18° 950	1385	227 B. Cnc	2448	29 Oph	3177	44 Cap
178	35 Cet	886	+18° 987	1395	12 B. Leo	2463	132 B. Oph	3181	45 Cap
210	117 G. Psc	888	+19° 1110	1415	7 Leo	2591	16 G. Sgr	3190	δ Cap
291	311 B. Psc	895	57 Ori	1420	11 Leo	2599	24 B. Sgr	3210	156 B. Cap
306	+6° 324	913	64 Ori	1434	ψ Leo	2633	μ Sgr	3236	−15° 6139
364	ξ^2 Cet	915	χ^2 Ori	1449	23 Leo	2638	15 Sgr	3237	ι Aqr
405	μ Cet	947	71 Ori	1466	ν Leo	2639	16 Sgr	3240	−15° 6143
444	+10° 401	991	16 Gem	1487	α Leo	2697	108 B. Sgr	3256	39 Aqr
453	+11° 434	995	ν Gem	1493	34 Leo m.	2704	115 B. Sgr	3275	45 Aqr
462	+11° 445	1006	22 Gem	1501	+12° 2177	2708	121 B. Sgr	3288	50 Aqr
491	8 B. Tau	1025	+19° 1430	1522	+11° 2217	2734	29 Sgr	3303	182 B. Aqr
498	+12° 477	1038	+18° 1338	1576	53 Leo	2739	31 Sgr	3327	−12° 6327
508	5 Tau	1060	+19° 1559	1625	308 B. Leo	2757	36 Sgr	3339	−11° 5912
516	+13° 568	1077	ζ Gem	1644	σ Leo	2759	ξ Sgr	3419	ψ^1 Aqr
526	+13° 579	1084	+19° 1623	1645	+7° 2440	2797	π Sgr	3421	χ_2 Aqr
608	179 B. Tau	1113	56 Gem	1648	358 B. Leo	2802	199 B. Sgr	3425	ψ^2 Aqr
618	+15° 592	1127	61 Gem	1923	−3° 3462	2851	253 B. Sgr	3428	ψ^3 Aqr
626	48 Tau	1130	+19° 1734	1950	80 Vir	2859	203 G. Sgr	3434	−9° 6173
635	γ Tau	1135	+19° 1743	1965	566 B. Vir	2892	292 B. Sgr	3446	−9° 6183 *f.*
667	75 Tau	1151	+19° 1784	2043	652 B. Vir	2938	349 B. (Sgr)	3478	351 B. Aqr
672	+15° 633 m.	1171	79 Gem	2047	654 B. Vir	3026	−19° 5905	3506	376 B. Aqr
677	264 B. Tau	1193	85 Gem	2072	8 G. Lib	3035	−19° 5928	4001	MERCURY
680	269 B. Tau	1202	+19° 1896	2089	8 B. Lib	3041	81 B. Cap	4006	SATURN
685	275 B. Tau	1203	+18° 1816	2128	13 Lib	3055	59 G. Cap	4007	URANUS
692	α Tau	1205	217 B. (Gem)	2158	−12° 4198	3057	90 B. Cap	5004	VESTA
729	+16° 657	1217	10 H. Cnc						

Date		Z.C. No.	Mag.	Ph.	Age of Moon	A Massachusetts W. 72·500, N. 42·500				B Montreal, Q.P. W. 73·575, N. 45·505				C Washington, D.C. W. 77·065, N. 38·920				D Toronto, Ont. W. 79·400, N. 43·663			
						U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Jan.	12	62	7·5	1	5·5	N				N				1 46·7	·	·	351	N			
	13	210	6·6	1	6·6	3 14·6	−0·7	−1·9	104	3 08·8	−0·7	−1·5	92	3 19·4	−0·9	−2·9	119	3 07·1	−0·9	−1·6	96
	14	453	7·3	1	8·5	23 37·9	−1·2	+2·3	37	23 44·1	−0·9	+2·7	25	23 24·1	−1·3	+2·3	41	23 34·0	−0·8	+3·0	23
	15	462	5·9	1	8·6	2 18·7	−1·7	−0·6	84	2 15·7	−1·6	−0·2	74	2 12·8	−2·1	−0·9	94	2 06·2	−1·8	0·0	76
	16	608	6·0	1	9·6	4 49·7	−0·8	−3·5	131	4 39·7	−1·0	−2·5	118	N				4 38·5	−1·2	−3·2	127
	23	1487	1·3	1	16·6	2 44·5	·	·	169	2 37·1	−0·9	−1·2	151	N				2 34·7	−0·9	−1·7	158
	23	1487	1·3	2	16·6	3 16·8	·	·	220	3 27·8	−1·1	+3·2	238	N				3 15·8	−0·8	+3·9	229
	23	4007	5·7	2	16·7	4 23·8	−1·5	−0·3	303	4 20·8	−1·3	−0·7	314	4 16·9	−1·5	+0·3	290	4 13·9	−1·3	−0·2	306
	29	2128	5·8	2	22·9	9 57·3	−2·1	+0·7	268	9 57·1	−1·8	+0·6	274	9 42·1	−2·7	+2·0	249	9 44·2	−2·0	+1·3	261
	30	2245	6·4	2	23·9	8 47·8	−1·3	+1·3	269	8 50·1	−1·1	+1·1	276	8 35·8	−1·4	+2·1	251	8 41·4	−1·1	+1·5	264
	31	2399	5·0	2	25·0	N				N				10 48·5	−0·4	−1·6	339	10 38·5	·	·	356
Feb.	8	20	6·8	1	3·0	H				H				H				1 05·1	−0·5	−1·6	98
	8	150	6·2	1	4·0	23 45·1	−1·3	−1·7	102	23 39·4	−1·2	−1·2	90	23 45·2	−1·8	−2·4	113	23 33·7	−1·5	−1·1	91
	9	165	6·7	1	4·0	H				H				1 58·5	−0·4	−0·7	73	1 55·3	−0·4	−0·3	56
	12	692	1·1	1	7·9	21 01·7	−1·2	+1·5	76	21 05·5	−1·0	+1·8	68	20 51·2	−1·1	+1·5	79	20 57·0	−0·8	+1·9	66
	12	692	1·1	2	7·9	22 19·0	−1·5	+1·5	247	22 21·5	−1·5	+1·2	256	22 06·2	−1·4	+1·8	242	22 10·4	−1·4	+1·4	258
	13	729	7·2	1	8·2	5 45·8	−0·3	−0·8	71	5 43·3	−0·4	−0·7	63	5 48·0	−0·3	−1·3	86	5 42·4	−0·4	−0·9	73
	13	832	4·7	1	9·0	22 39·0	−1·3	+2·1	59	22 44·5	−1·1	+2·4	49	S				S			
	13	836	5·5	1	9·0	23 24·0	−1·9	+0·8	86	23 25·3	−1·6	+1·2	76	23 12·6	−1·9	+0·7	93	23 13·7	−1·5	+1·4	76
	14	862	7·5	1	9·2	N				N				5 23·1	−1·8	+2·2	29	N			
	14	863	6·7	1	9·2	N				N				5 35·1	−1·6	+1·7	32	N			
	14	871	6·9	1	9·2	6 26·3	−0·2	−1·2	87	6 22·4	−0·3	−1·1	80	6 30·1	−0·2	−1·5	100	6 22·6	−0·4	−1·3	89
	15	1006	6·9	1	10·2	4 28·2	−1·6	−0·4	71	4 25·8	−1·6	0·0	62	4 22·7	−1·7	−0·8	86	4 16·1	−1·8	−0·2	72
	16	1130	7·2	1	11·2	4 47·9	−1·8	−0·5	77	4 45·0	−1·8	−0·1	69	4 42·0	−1·9	−0·9	93	4 34·5	−1·9	−0·3	80
	17	1241	6·4	1	12·1	N				1 30·7	·	·	153	N				1 26·9	·	·	164
	17	1262	6·2	1	12·3	8 57·3	+0·3	−2·6	147	8 50·2	+0·2	−2·4	141	9 10·1	+0·7	−3·5	165	8 56·3	+0·3	−2·9	152
	19	1487	1·3	1	14·4	H				11 35·2	−0·2	+0·1	42	11 37·1	0·0	−0·6	64	11 34·3	−0·3	−0·4	53
Mar.	4	4001	0·3	1	27·5	11 34·1	−1·3	+3·0	28	11 42·1	·	·	19	11 18·9	−1·1	+2·5	41	11 29·3	−1·1	+2·9	29
	4	4001	0·3	2	27·5	12 20·1	−1·2	−0·1	311	12 18·4	·	·	319	12 14·4	−1·1	+0·3	300	12 13·3	−0·8	+0·1	311
	12	667	5·3	1	5·6	2 41·9	−0·5	−1·2	85	2 38·1	−0·6	−1·0	76	2 44·2	−0·6	−1·5	99	2 36·1	−0·8	−1·2	85
	12	672	6·6	1	5·7	3 09·4	+0·2	−3·6	140	3 00·1	−0·1	−2·8	127	N				3 05·6	0·0	−4·0	142
	12	677	4·8	1	5·7	3 52·8	+0·5	−3·3	141	3 44·3	+0·2	−2·6	129	N				3 51·6	+0·4	−3·9	145
	12	680	6·7	1	5·7	N				3 57·6	+0·6	−4·1	148	N				N			
	13	823	6·6	1	6·8	H				H				H				5 34·2	+0·1	−1·3	92
	14	947	5·2	1	7·6	1 19·4	−1·5	−3·5	139	1 08·9	−1·6	−2·4	126	G				1 04·1	−1·8	−3·2	136
	15	1084	7·3	1	8·6	1 57·0	·	·	35	N				1 37·5	−2·5	+1·4	58	1 42·9	·	·	35
	16	1203	7·1	1	9·6	1 25·9	−1·9	−2·0	129	1 19·0	−1·8	−1·3	119	1 26·6	−1·9	−3·5	148	1 10·6	−1·9	−1·6	128
	16	1236	5·1	1	9·9	H				H				H				8 05·8	+0·2	−1·7	115
	17	1420	6·6	1	11·6	23 55·0	−1·5	+3·7	52	24 09·3	·	·	30	S				S			
	18	1449	6·7	1	11·9	8 43·4	−0·2	−1·2	80	8 39·7	−0·2	−1·2	75	8 47·0	−0·2	−1·3	90	8 40·2	−0·4	−1·3	83
	20	1644	4·1	1	13·8	7 56·1	·	·	186	7 43·8	+0·1	−3·8	176	N				N			
	31	4006	0·9	1	25·0	9 48·0	−0·7	−0·4	139	9 47·1	−0·7	+0·2	131	9 52·4	·	·	164	9 43·7	−0·4	−0·3	141
	31	4006	0·9	2	25·0	10 26·9	−1·6	+2·9	204	10 32·9	−1·4	+2·3	212	10 03·2	·	·	182	10 19·5	−1·5	+3·0	204
Apr.	7	453	7·3	1	2·2	H				H				H				0 59·9	−0·1	−1·3	92
	8	692	1·1	2	3·8	H				13 27·4	+0·3	+1·3	262	H				H			
	11	1060	7·4	1	6·3	H				4 50·6	+0·3	−1·9	123	H				4 56·4	+0·4	−2·2	133
	15	1501	7·3	1	10·3	2 20·8	−1·6	−1·7	125	2 14·4	−1·7	−1·4	118	2 20·9	−1·5	−2·4	141	2 07·5	−1·6	−1·7	130
	22	2245	6·4	2	17·4	N				N				3 50·4	0·0	−1·9	344	3 38·0	·	·	7
	22	2247	5·6	2	17·4	G				4 49·4	·	·	230	N				N			
May	9	1130	7·2	1	4·9	N				2 42·3	·	·	170	N				N			
	22	2633	4·0	1	18·1	4 50·6	−1·5	+0·8	97	4 51·6	−1·4	+0·9	92	4 42·1	−1·2	+0·5	109	4 42·5	−1·2	+0·8	101
	22	2633	4·0	2	18·1	6 10·8	−1·9	+0·2	279	6 09·6	−1·7	+0·2	283	6 00·6	−2·0	+0·6	269	5 59·1	−1·7	+0·6	276
	23	2797	3·0	2	19·0	5 02·5	−1·2	+0·8	282	5 03·8	−1·0	+0·8	287	4 53·8	−1·1	+1·1	270	H			
	25	3086	6·0	2	21·1	6 05·6	−0·8	+0·7	293	H				H				H			
	26	3237	4·4	2	22·1	N				N				6 51·6	·	·	321	N			
June	6	1202	6·9	1	3·5	1 54·9	−0·1	−1·0	75	1 51·9	−0·2	−0·9	70	1 58·2	−0·1	−1·1	87	1 52·4	−0·3	−1·1	79
	8	1434	5·6	1	5·5	2 31·6	−0·1	−2·0	123	2 25·5	−0·2	−2·0	119	2 38·6	−0·1	−2·2	134	2 27·9	−0·3	−2·1	127
	10	1645	6·6	1	7·6	H				H				H				4 47·8	−0·1	−2·0	128
	13	1950	5·8	1	10·6	4 04·5	−1·4	−1·2	84	3 59·5	−1·5	−1·1	80	4 01·9	−1·6	−1·3	95	3 52·3	−1·7	−1·1	88
	16	2291	5·5	1	13·6	2 40·9	−1·8	−0·4	114	2 38·3	−1·7	−0·1	110	2 34·8	−1·6	−0·6	127	2 29·4	−1·5	−0·2	120
	19	2759	3·6	1	16·7	7 33·0	−1·3	+0·6	41	7 33·7	−1·1	+0·8	33	7 24·0	−1·6	+0·7	47	7 24·8	−1·4	+1·1	33
	19	2759	3·6	2	16·7	8 29·3	−1·8	−2·0	307	8 20·7	−1·9	−2·3	316	8 27·4	−2·0	−1·8	302	8 12·9	−2·1	−2·2	318
	27	364	4·3	1	24·8	8 14·4	−0·2	+2·1	42	8 20·7	−0·1	+2·2	36	8 06·4	−0·1	+2·0	45	8 16·2	0·0	+2·2	35
	27	364	4·3	2	24·8	S				S				9 03·0	−0·8	+1·3	267	S			
July	13	2247	5·6	1	11·2	H				H				H				5 25·2	−1·1	−2·6	145
	20	3303	6·2	2	18·3	5 50·8	−1·3	+1·7	219	5 54·2	−1·3	+1·5	225	5 37·9	−1·3	+2·1	215	5 43·7	−1·3	+1·7	226
Aug.	12	2599	6·8	1	11·6	3 56·3	−0·9	+0·7	36	3 58·4	·	·	24	3 48·6	−1·4	+0·7	43	3 50·9	·	·	25
	13	2759	3·6	1	12·6	1 39·7	−2·1	+2·0	35	1 44·1	·	·	26	1 22·7	−2·2	+1·8	48	1 27·4	−2·2	+2·3	36
	27	1259	5·9	2	26·9	8 43·7	0·0	+1·0	279	8 46·6	−0·1	+0·9	288	H				H			
Sept.	4	2043	6·6	1	4·9	H				H				1 06·4	−0·7	−0·9	73	1 00·6	−0·8	−0·8	62

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				d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Sept. 9	2704	5·8	1	10·0	H				H				4 11·2	−1·4	−2·0	118	4 00·0	−1·2	−1·5	104
10	2851	6·0	1	10·9	1 17·1	·	·	149	1 09·4	−2·0	−1·3	139	G				1 00·1	−1·9	−1·3	142
10	2859	6·7	1	11·0	3 47·0	−1·0	−0·2	58	3 45·4	−0·9	−0·1	50	3 42·5	−1·3	−0·1	61	3 39·9	−1·1	+0·1	48
11	4006	0·6	1	12·0	2 56·5	−2·3	−1·4	122	2 50·7	−2·0	−0·9	114	2 50·3	−2·6	−1·5	126	2 40·2	−2·1	−0·6	112
11	4006	0·6	2	12·0	3 47·6	−0·7	+1·1	206	3 49·1	−0·9	+0·5	216	3 39·4	−0·8	+1·6	203	3 42·2	−1·1	+0·7	219
17	364	4·3	1	18·1	4 12·4	−0·8	+1·7	64	4 16·8	−0·7	+1·8	58	4 03·0	−0·7	+1·6	66	4 09·8	−0·5	+1·8	56
17	364	4·3	2	18·1	5 20·0	−1·2	+1·6	243	5 23·2	−1·2	+1·4	250	5 09·0	−1·1	+1·7	241	5 13·9	−1·1	+1·5	253
18	491	6·2	2	19·1	4 39·3	−0·5	+2·0	231	4 44·5	−0·5	+1·9	238	4 30·2	−0·3	+2·0	229	4 38·3	−0·4	+1·8	241
18	498	6·2	2	19·1	N				5 57·4	+0·3	+4·0	184	N				5 52·6	+0·1	+3·5	190
Oct. 10	3240	6·6	1	11·3	3 05·9	−2·1	−1·2	106	3 00·9	−1·8	−0·8	97	2 59·6	−2·5	−1·2	109	2 51·1	−1·9	−0·4	93
17	764	5·0	2	18·6	S				S				10 25·7	−1·8	+1·4	225	10 25·5	−1·6	+0·3	243
18	888	6·0	2	19·3	3 05·9	−0·5	+0·3	308	3 05·6	−0·7	−0·2	320	3 03·1	−0·3	+0·3	303	H			
18	895	5·9	2	19·4	4 18·3	−0·3	+1·7	251	4 22·9	−0·4	+1·6	259	4 11·2	−0·1	+1·7	247	4 18·3	−0·2	+1·5	260
18	915	4·7	2	19·5	9 18·0	−1·9	+0·6	254	9 17·1	−1·8	+0·2	265	9 05·4	−2·0	+1·4	243	9 05·6	−1·9	+0·6	261
19	1077	4·1	1	20·6	9 39·4	−2·0	+1·2	68	9 41·9	−1·9	+1·8	57	9 26·3	−2·1	+0·9	80	9 28·0	−1·8	+1·8	63
19	1077	4·1	2	20·6	S				S				10 53·1	−2·1	−0·9	283	10 42·9	−1·9	−1·5	299
20	1193	5·4	2	21·5	G				N				8 05·1	−2·1	−2·4	329	N			
21	1310	4·2	2	22·5	N				N				5 57·0	·	·	345	N			
24	1625	5·9	2	25·6	9 10·2	−0·6	+1·3	273	9 13·2	−0·5	+1·0	284	9 02·5	−0·4	+1·7	261	9 08·5	−0·3	+1·2	278
Nov. 2	2739	6·7	1	5·4	23 37·5	−1·7	−1·8	116	23 30·8	−1·5	−1·5	108	23 35·5	−2·0	−1·9	120	23 23·8	−1·8	−1·3	107
3	2892	6·8	1	6·4	23 37·3	−1·0	+0·5	40	23 38·1	−0·8	+0·7	31	23 29·7	−1·4	+0·7	44	23 31·1	−1·0	+1·1	29
4	4006	0·8	2	7·2	18 01·5	−0·1	−0·2	320	H				H				H			
4	3026	7·3	1	7·4	22 56·4	−1·8	+0·2	72	22 55·4	−1·7	+0·3	66	22 46·2	−2·1	+0·4	75	22 44·4	−1·8	+0·7	65
5	3035	6·8	1	7·5	1 41·2	−2·3	−3·3	132	1 31·2	−1·8	−2·1	118	1 42·2	·	·	139	1 23·9	−2·0	−1·8	114
5	3171	3·8	1	8·4	22 40·1	−2·2	−0·2	110	22 37·9	−1·9	+0·2	104	22 30·3	−2·3	−0·2	114	22 26·3	−1·8	+0·4	103
7	3327	6·8	1	9·5	1 59·5	−2·7	−2·2	120	1 51·9	−2·1	−1·3	107	1 54·4	·	·	124	1 41·4	−2·2	−0·8	102
7	3339	6·7	1	9·6	H				N				5 02·0	0·0	+1·3	21	N			
8	3478	6·5	1	10·5	0 49·6	−1·6	+0·9	60	0 51·0	−1·4	+1·1	53	0 38·4	−1·7	+1·2	61	0 40·8	−1·4	+1·4	50
15	991	6·1	2	17·6	3 36·8	−0·6	+1·5	259	3 40·4	−0·7	+1·4	268	3 28·7	−0·4	+1·6	255	3 34·4	−0·5	+1·3	269
19	1493	6·4	2	21·8	7 53·1	−1·3	+0·3	294	7 52·3	−1·1	0·0	305	7 45·6	−1·1	+0·8	282	7 45·7	−1·0	+0·3	299
Dec. 4	3288	5·9	1	6·8	0 49·0	−1·3	−0·5	75	0 46·4	−1·1	−0·3	66	0 44·3	−1·6	−0·4	78	0 39·8	−1·3	−0·1	63
5	3425	4·6	1	7·7	0 16·6	−1·5	+0·3	62	0 16·3	−1·3	+0·5	54	0 07·7	−1·7	+0·5	64	0 07·3	−1·4	+0·8	50
5	3434	7·4	1	7·8	2 25·6	−0·7	+0·1	49	2 25·6	−0·6	+0·4	38	2 21·2	−1·0	+0·2	54	2 21·1	−0·7	+0·6	37
5	3446	7·2	1	7·9	3 43·6	−0·5	−0·6	68	3 41·7	−0·4	−0·4	57	3 43·4	−0·7	−0·7	75	3 39·6	−0·6	−0·3	58
6	25	7·5	1	8·8	1 41·1	−1·3	+0·3	59	1 41·0	−1·1	+0·5	49	1 33·1	−1·6	+0·4	62	1 32·8	−1·2	+0·8	46
7	291	7·1	1	10·8	23 27·2	−1·2	+1·6	63	23 30·9	−1·0	+1·7	56	23 16·2	−1·1	+1·6	64	23 22·1	−0·9	+1·8	53
8	306	6·9	1	10·9	3 30·5	−0·9	+1·9	23	3 36·9	−0·5	+3·0	8	3 19·2	−1·2	+1·8	31	3 28·3	−0·5	+3·2	8
13	1077	3·8	1	16·0	N				4 29·6	−2·0	−2·3	144	N				4 21·6	·	·	148
13	1077	3·8	2	16·0	N				5 12·3	−1·3	+4·1	211	N				4 57·7	·	·	205
14	1193	5·4	2	16·8	2 03·0	−0·2	+1·6	259	2 07·2	−0·3	+1·4	268	1 56·8	0·0	+1·6	253	2 03·6	−0·1	+1·3	268
14	1205	6·3	2	16·9	4 37·6	−1·2	+2·0	247	4 41·7	−1·2	+1·6	258	4 24·5	−0·9	+2·5	237	4 32·1	−1·0	+1·7	255
21	1965	6·5	2	24·1	8 13·8	−0·4	−0·1	313	8 12·8	−0·3	−0·4	323	8 11·3	−0·4	+0·4	298	H			
30	3236	7·1	1	4·0	22 05·9	−1·0	+0·5	42	22 06·8	−0·8	+0·7	33	S				S			

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				d	h m	m	m	°
Jan. 8	3167	7·1	1	2·4	23 49·6	−0·8	−0·5	75
12	62	7·5	1	5·5	1 25·3	−0·6	+2·4	16
15	462	5·9	1	8·6	2 00·2	−2·9	−1·6	109
23	4007	5·7	2	16·7	4 01·1	−1·3	+1·2	268
31	2399	5·0	2	25·0	10 47·5	−1·0	−0·3	307
Feb. 8	150	6·2	1	4·0	23 47·7	·	·	137
9	165	6·7	1	4·0	1 59·6	−0·7	−1·2	92
10	306	6·9	1	5·1	3 48·9	−0·3	−1·0	89
12	692	1·1	1	7·9	20 35·6	−0·8	+1·2	84
12	692	1·1	2	7·9	21 45·0	−1·0	+2·1	236
13	729	7·2	1	8·2	5 54·0	−0·3	−1·8	111
14	862	7·5	1	9·2	5 06·1	−1·6	0·0	65
14	863	6·7	1	9·2	5 20·4	−1·5	−0·1	66
14	871	6·9	1	9·2	6 39·8	−0·1	−2·4	127
15	1006	6·9	1	10·2	4 15·1	−2·0	−1·7	112
16	1130	7·2	1	11·2	4 34·3	−2·1	−1·9	119
19	1487	1·3	1	14·4	11 41·2	−0·1	−1·0	84
Mar. 4	4001	0·3	2	27·5	12 03·3	−0·9	+0·8	281
11	516	7·3	1	4·6	3 04·9	−0·8	+1·6	28
12	667	5·3	1	5·6	2 51·4	−0·6	−2·9	128

Date	Z.C. No.	Mag.	Ph.	Age of Moon	E ALABAMA–GEORGIA W. 85·000, N. 33·000 U.T.	a	b	P
				d	h m	m	m	°
Mar. 15	1084	7·3	1	8·6	1 12·2	−2·6	+0·4	83
18	1434	5·6	1	11·7	3 38·8	−3·4	+1·5	69
18	1449	6·7	1	11·9	8 53·6	−0·2	−1·6	109
31	3041	6·4	2	25·0	10 01·8	−1·3	+2·2	228
Apr. 7	453	7·3	1	2·2	1 23·6	+0·4	−4·6	144
15	1501	7·3	1	10·3	2 35·1	·	·	182
22	2245	6·4	2	17·4	3 52·6	−0·7	−0·3	310
25	2697	6·5	2	20·6	9 47·9	−2·4	−0·9	300
May 9	1135	6·8	1	4·9	3 29·7	·	·	34
22	2633	4·0	1	18·1	4 34·0	−0·6	−0·5	135
22	2633	4·0	2	18·1	5 38·1	−2·2	+1·6	247
22	2638	5·4	2	18·1	6 03·0	·	·	347
June 6	1202	6·9	1	3·5	2 05·2	−0·1	−1·5	109
8	1434	5·6	1	5·5	2 54·0	+0·2	−3·1	159
10	1645	6·6	1	7·6	5 11·6	+0·1	−2·6	153
13	1950	5·8	1	10·6	3 56·4	−1·9	−1·6	114
16	2291	5·5	1	13·6	2 31·2	−0·9	−1·9	155
19	2759	3·6	1	16·7	7 03·5	−2·3	+0·9	58
19	2759	3·6	2	16·7	8 19·6	−2·3	−1·4	294
27	364	4·3	2	24·8	8 50·7	−0·4	+1·3	262

Date	Z.C. No.	Mag.	Ph.	Age of Moon	E Alabama–Georgia W. 85·000, N. 33·000 U.T.	a	b	P
				d	h m	m	m	o
July 12	2128	5·8	1	10·2	5 17·7	−1·0	−1·3	94
14	2390	6·7	1	12·2	6 18·1	−1·2	−0·7	77
20	3303	6·2	2	18·3	5 13·1	−1·3	+2·9	204
Aug. 12	2599	6·8	1	11·6	3 30·4	−2·2	+0·7	56
13	2759	3·6	1	12·6	0 55·8	−2·0	+1·4	70
Sept. 4	2043	6·6	1	4·9	1 05·7	−1·1	−1·1	87
4	2047	6·7	1	4·9	1 29·3	−0·8	−1·6	107
9	2704	5·8	1	10·0	4 10·5	−2·0	−2·3	126
9	2708	5·9	1	10·0	4 44·3	−0·6	+0·2	51
10	2859	6·7	1	11·0	3 30·3	−1·8	+0·1	67
11	4006	0·6	1	12·0	2 38·4	·	·	137
11	4006	0·6	2	12·0	3 18·8	·	·	194
17	364	4·3	1	18·1	3 49·0	−0·5	+1·5	71
17	364	4·3	2	18·1	4 51·4	−0·8	+1·8	238
18	491	6·2	2	19·1	4 16·8	−0·1	+2·0	224
Oct. 10	3240	6·6	1	11·3	2 44·4	−3·0	−1·1	113
17	764	5·0	2	18·6	9 52·7	·	·	193
18	895	5·9	2	19·4	4 01·6	+0·2	+1·6	242
18	915	4·7	2	19·5	8 38·6	−1·7	+2·6	226

Date	Z.C. No.	Mag.	Ph.	Age of Moon	E Alabama–Georgia W. 85·000, N. 33·000 U.T.	a	b	P
				d	h m	m	m	o
Oct. 19	1077	4·1	1	20·6	9 05·9	−2·2	+0·3	97
19	1077	4·1	2	20·6	10 35·4	−2·5	+0·6	261
20	1193	5·4	2	21·5	7 58·5	−1·6	−0·7	309
Nov. 2	2739	6·7	1	5·4	23 28·8	−2·6	−2·1	128
7	3327	6·8	1	9·5	1 40·9	·	·	129
7	3339	6·7	1	9·6	4 54·0	−0·4	+1·0	33
8	3478	6·5	1	10·5	0 17·2	−1·7	+1·4	64
15	991	6·1	2	17·6	3 17·3	−0·1	+1·5	248
16	1127	5·9	2	18·7	3 41·8	+0·2	+1·9	236
18	1395	6·3	2	20·9	9 31·7	−1·9	−2·7	328
19	1493	6·4	2	21·8	7 31·1	−0·8	+1·5	263
Dec. 4	3288	5·9	1	6·8	0 31·6	−2·1	−0·2	81
4	3303	6·2	1	6·9	3 52·8	−0·7	−1·3	96
4	3425	4·6	1	7·7	23 48·4	−2·1	+0·9	65
5	3434	7·4	1	7·8	2 10·4	−1·4	+0·3	60
5	3446	7·2	1	7·9	3 41·0	−1·2	−0·9	87
6	25	7·5	1	8·8	1 15·3	−2·0	+0·8	65
8	306	6·9	1	10·9	2 58·1	−1·5	+1·9	39
14	1205	6·3	2	16·9	4 02·4	−0·2	+3·4	220
31	3256	6·2	1	4·1	1 29·2	−0·4	+0·1	54

Date	Z.C. No.	Mag.	Ph.	Age of Moon	F Illinois W. 91·000, N. 40·000 U.T.	a	b	P	G Texas W. 98·000, N. 31·000 U.T.	a	b	P	H Denver, Colo. W. 104·950, N. 39·677 U.T.	a	b	P	I N. Mex.–Ariz. W. 109·000, N. 34·000 U.T.	a	b	P
				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Jan. 8	3167	7·1	1	2·4	23 44·0	−0·6	+0·2	47		S				S				S		
9	3177	6·0	1	2·5		H				H				H			2 04·2	−0·1	+0·8	34
12	62	7·5	1	5·5		N			1 14·5	·	·	358		N				N		
12	76	5·9	1	5·6		N			4 21·6	−0·3	+1·6	24		N			4 28·5	·	·	353
12	83	6·9	1	5·7		H				H			5 15·3	−0·3	+0·2	45	5 14·0	−0·5	−0·2	65
13	210	6·6	1	6·6	2 59·5	−1·5	−1·8	103		N			2 35·3	−2·0	−0·7	89	2 31·8	−2·7	−1·4	105
15	462	5·9	1	8·6	1 43·1	−2·0	+0·5	77	1 23·6	−2·8	0·0	95	1 17·0	−1·6	+1·6	60	1 01·5	−1·7	+1·4	69
15	5004	7·1	1	8·6		N			5 02·0	·	·	359		N				N		
16	608	6·0	1	9·6		G				N			4 01·2	·	·	137		N		
16	618	7·2	1	9·7		N			6 39·7	−1·7	+3·2	22		N				G		
23	1487	1·3	1	16·6	2 34·3	·	·	174		N				H				N		
23	1487	1·3	2	16·6	2 54·2	·	·	210		N			2 57·7	+0·4	+3·5	224		N		
23	4007	5·7	2	16·7	4 00·3	−0·9	+0·5	293	3 46·5	−0·6	+1·4	264	3 50·2	−0·5	+0·4	297	3 45·1	−0·3	+0·8	280
31	2399	5·0	2	25·0	10 40·9	−0·5	−0·4	320	10 35·3	−0·8	+0·5	284		H				H		
Feb. 8	20	6·8	1	3·0	1 03·2	−1·0	−1·9	104		N				S				S		
9	165	6·7	1	4·0	1 49·9	−0·8	−0·3	65	1 48·6	−1·3	−1·1	92	1 36·6	−1·1	+0·2	56	1 30·8	−1·5	−0·1	71
9	170	6·2	1	4·1		H			3 17·1	−0·5	+0·1	57	3 20·3	−0·4	+1·7	19	3 11·9	−0·7	+0·7	42
9	178	6·8	1	4·1		H				H			4 01·8	−0·3	−0·2	57	4 02·4	−0·5	−0·6	76
10	306	6·9	1	5·1	3 41·6	−0·5	−0·4	65	3 45·0	−0·7	−1·3	97	3 32·2	−0·9	−0·3	64	3 31·0	−1·2	−0·8	83
12	692	1·1	1	7·9	20 43·3	−0·4	+1·9	61	20 26·3	−0·2	+1·4	75	20 41·0	+0·1	+2·1	48	20 30·9	+0·2	+1·7	57
12	692	1·1	2	7·9	21 50·5	−1·1	+1·4	262	21 30·4	−0·7	+1·6	248	21 37·1	−0·8	+1·1	277	21 28·2	−0·5	+1·2	268
13	729	7·2	1	8·2	5 39·9	−0·7	−1·4	92	5 53·2	−0·5	−3·0	131	5 27·1	−1·2	−1·6	101	5 34·2	−1·3	−2·9	125
14	862	7·5	1	9·2	4 59·9	−1·9	+1·4	41	4 42·3	−2·1	−0·3	81	4 31·6	−2·1	+1·4	50	4 17·1	−2·4	+0·5	72
14	863	6·7	1	9·2	5 13·5	−1·8	+1·1	44	4 58·8	−2·0	−0·5	83	4 46·4	−2·1	+1·1	54	4 34·1	−2·3	+0·2	76
14	871	6·9	1	9·2	6 22·6	−0·6	−1·9	110	6 46·4	·	·	157	6 12·0	−1·1	−2·5	122	6 29·2	·	·	155
15	1006	6·9	1	10·2	3 54·7	−2·1	−0·5	90	3 49·2	−2·6	−2·3	125	3 23·7	−2·2	+0·2	92	3 15·3	−2·6	−0·7	110
15	1025	7·4	1	10·3		N			7 34·4	·	·	36		N			7 15·0	−2·4	+2·0	41
16	1130	7·2	1	11·2	4 12·2	−2·2	−0·6	99	4 09·2	−2·5	−2·8	135	3 41·3	−2·2	−0·1	102	3 35·2	−2·4	−1·2	122
16	1151	6·8	1	11·4		N			10 14·0	−0·7	+0·7	46		N			10 05·5	−1·1	+0·2	53
19	1487	1·3	1	14·4	11 32·9	−0·5	−0·9	73	11 40·1	−0·4	−1·3	100	11 24·2	−0·9	−1·3	87	11 28·9	−0·8	−1·6	104
19	1487	1·3	2	14·4	12 20·5	+0·3	−2·3	327	12 40·2	+0·2	−1·7	302	12 23·9	0·0	−2·2	316	12 35·1	−0·1	−1·8	301
26	2223	4·0	1	21·5		S				S			13 01·3	−1·9	−1·2	121	13 01·9	−1·9	−1·8	137
Mar. 1	2639	6·0	2	24·5		S			11 32·4	−1·8	+1·0	264	11 30·4	−1·1	+0·9	279	11 19·3	−1·3	+1·4	259
11	516	7·3	1	4·6		N			2 50·2	−1·1	+0·9	45		N			2 39·7	−1·4	+1·7	33
11	526	6·9	1	4·7		H				H				H			5 26·8	−0·2	−0·6	76
12	667	5·3	1	5·6	2 30·3	−1·2	−1·7	102	2 49·6	·	·	151	2 10·4	−1·8	−1·6	105	2 15·9	−2·2	−3·6	131
12	692	1·1	1	5·8		H				H			6 11·5	+0·3	−2·2	124	6 33·5	·	·	164
12	692	1·1	2	5·8		H				H			6 55·0	−0·1	+0·1	227	6 45·3	·	·	188
13	823	6·6	1	6·8	5 40·3	0·0	−1·8	112	6 07·2	·	·	161	5 39·4	−0·2	−2·6	127	6 01·9	·	·	166
13	832	4·7	1	6·8		H				H			6 57·2	−0·2	−0·8	73	7 02·0	−0·1	−1·1	93
15	1084	7·3	1	8·6	1 06·3	−2·2	+2·1	57		S				S				S		
16	1203	7·1	1	9·6	0 54·7	−2·1	−2·7	146		N				S				N		

Date	Z.C. No.	Mag.	Ph.	Age of Moon	F ILLINOIS W. 91·000, N. 40·000				G TEXAS W. 98·000, N. 31·000				H DENVER, COLO. W. 104·950, N. 39·677				I N. MEX.–ARIZ. W. 109·000, N. 34·000			
					U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Mar. 16	1236	5·1	1	9·9	8 15·3	+0·2	−2·2	133	8 45·4	·	·	176	8 18·8	+0·2	−3·0	151		N		
16	1241	6·4	1	9·9		H				H			9 06·2	0·0	−1·7	112	9 17·0	+0·2	−2·1	130
18	1434	5·6	1	11·7		G			2 59·1	−2·5	+0·6	91	2 57·5	−2·2	+3·1	59	2 37·8	−1·8	+1·3	84
18	1449	6·7	1	11·9	8 40·0	−0·6	−1·6	100	8 52·5	−0·5	−2·1	127	8 30·2	−0·9	−1·9	116	8 38·9	−0·8	−2·4	134
27	2448	6·4	2	21·0		S				S			11 36·1	−1·8	−1·3	318	11 34·3	−2·1	−0·8	302
29	2734	5·4	2	23·0		N			8 42·9	+0·2	−1·5	331		N				H		
31	3058	5·9	2	25·1		S				S				S			12 07·6	·	·	194
Apr. 7	453	7·3	1	2·2	1 03·3	−0·4	−2·0	111		N				S				S		
11	1060	7·4	1	6·3	5 12·9	+0·9	−4·1	163		N				N				N		
14	1415	6·2	1	9·4		N			7 34·2	−0·9	−0·3	65	7 26·5	·	·	44	7 20·5	−1·4	−0·6	73
15	1501	7·3	1	10·3	1 58·1	−1·3	−3·1	157		N				S				N		
22	2245	6·4	2	17·4	3 46·8	−0·2	−0·6	326	3 44·4	−0·5	+0·5	288		H				H		
25	2697	6·5	2	20·6	9 29·4	−1·7	−0·9	315	9 20·1	−2·0	0·0	288	9 08·4	−1·3	0·0	303	9 01·5	−1·5	+0·4	286
25	2708	5·9	2	20·6		S				S				S			11 17·0	−2·4	+0·6	256
May 9	1135	6·8	1	4·9		N			3 13·6	−1·2	−0·3	68	3 04·8	−1·9	+0·9	46	2 57·5	−1·6	−0·4	74
22	2633	4·0	1	18·1		H			4 36·9	·	·	169		H				N		
22	2633	4·0	2	18·1	5 36·9	−1·6	+1·3	259	5 03·2	·	·	214		H				N		
22	2638	5·4	2	18·1		N			5 57·0	−0·9	−0·7	316	5 45·7	0·0	−1·3	336	5 48·1	−0·5	−0·2	310
25	3105	6·2	2	21·2		S			9 12·0	−1·8	+2·8	211	9 19·5	−1·5	+1·8	233	9 01·2	−1·5	+2·6	218
June 6	1202	6·9	1	3·5		S			2 07·0	−0·2	−2·2	130		S				S		
6	1217	6·1	1	3·6		H				H			3 56·5	−0·5	−0·3	55	3 57·9	−0·3	−0·7	76
8	1434	5·6	1	5·5	2 33·7	−0·2	−2·8	148		N				S				N		
10	1645	6·6	1	7·6	4 54·0	−0·2	−2·4	141	5 19·0	+0·2	−3·7	172	4 50·7	−0·3	−2·9	156	5 09·9	·	·	179
10	1648	7·0	1	7·6		H			6 01·2	−0·1	−2·0	131	5 42·2	−0·5	−1·9	119	5 52·1	−0·4	−2·2	133
13	1950	5·8	1	10·6	3 34·9	−2·0	−1·2	107	3 35·2	−1·8	−2·0	136	3 08·5	−1·8	−1·2	127	3 10·9	−1·4	−2·0	147
14	2072	6·7	1	11·7		H			7 55·9	−0·8	−1·5	104	7 37·4	−1·1	−1·2	86	7 39·7	−1·3	−1·4	98
16	2291	5·5	1	13·6	2 17·1	−0·8	−0·8	144		N				S				N		
19	2759	3·6	1	16·7	6 59·4	−2·1	+1·7	39	6 29·8	−2·4	+1·3	65	6 28·1	−2·2	+2·0	46	6 09·2	−2·0	+1·6	65
19	2759	3·6	2	16·7	7 54·4	−2·3	−1·8	317	7 49·8	−2·5	−0·9	296	7 25·4	−1·9	−1·1	317	7 22·3	−2·0	−0·6	302
21	4006	0·6	1	18·7		N			6 05·4	·	·	17		N			5 57·9	·	·	16
21	4006	0·6	2	18·7		N			6 36·0	·	·	328		N			6 22·7	·	·	332
24	3506	6·3	2	21·8	9 04·4	−0·7	+3·0	192		N			8 53·2	−0·7	+2·7	203	8 32·9	−0·6	+3·9	186
27	364	4·3	2	24·8	8 56·3	−0·4	+1·0	281		H				H				H		
July 12	2128	5·8	1	10·2	5 02·8	−1·3	−1·0	80	5 02·8	−1·7	−1·3	100	4 40·6	−1·9	−0·9	86	4 37·8	−2·2	−1·1	100
13	2247	5·6	1	11·2	5 20·0	−1·4	−2·8	152		N			5 00·2	−1·5	−2·7	157		G		
14	2390	6·7	1	12·2	6 07·9	−1·3	−0·1	57	5 59·0	−2·0	−0·4	77	5 44·8	−2·1	+0·4	56	5 34·2	−2·5	+0·1	72
20	3303	6·2	2	18·3	5 22·8	−1·1	+2·1	222	4 51·5	−1·1	+3·7	195		H				H		
21	3478	6·5	2	19·4		S				G			10 12·8	−1·2	+1·8	212	9 56·3	−1·1	+2·4	204
25	462	5·9	2	23·4	9 25·7	−1·8	−0·2	304	9 13·5	−1·1	+0·5	287		N			9 01·6	·	·	316
26	608	6·0	2	24·5		S			9 52·4	·	·	175	10 22·0	−0·1	+2·3	219	10 08·5	+0·2	+2·5	210
Aug. 10	2341	7·2	1	9·7		H				H				H			6 24·5	−1·1	−1·8	114
11	2463	6·9	1	10·7	5 41·2	−0·7	−0·4	58	5 38·2	−1·3	−0·5	75	5 27·9	−1·3	+0·3	48	5 20·7	−1·8	+0·1	62
12	2599	6·8	1	11·6	3 26·2	·	·	34	2 56·0	−2·7	+1·1	63	2 51·2	−2·6	+2·1	44		S		
13	2797	3·0	1	12·8		H			7 41·4	−1·2	−0·9	90	7 28·7	−1·0	−0·2	60	7 25·1	−1·4	−0·2	70
13	2797	3·0	2	12·8		H				H				H			8 36·7	−1·1	−1·1	271
17	3419	4·5	1	16·9		N				N			10 29·1	·	·	136		N		
17	3419	4·5	2	16·9		N				N			10 49·2	·	·	169		N		
Sept 4	2047	6·7	1	4·9	1 12·7	−1·1	−1·5	94	1 18·3	−1·4	−1·8	114		S				S		
5	2158	7·3	1	6·0		H			3 00·8	−0·9	−1·6	107	2 41·0	−1·2	−1·3	88	2 43·2	−1·5	−1·4	100
6	2280	6·8	1	7·0		H				H				N			4 09·4	·	·	40
9	2704	5·8	1	10·0	3 48·2	−1·7	−1·2	101	3 46·1	−2·4	−1·6	117	3 22·1	−2·1	−0·5	94	3 16·4	−2·4	−0·7	104
9	**2708**	5·9	1	10·0	4 49·7	·	·	13	4 32·7	−1·0	+1·0	41		N				G		
10	2859	6·7	1	11·0	3 23·3	−1·5	+0·8	45	3 02·6	−2·3	+0·8	62	2 58·7	−1·9	+1·7	38	2 41·0	−2·3	+1·5	52
11	4006	0·6	1	12·0	2 17·3	−2·0	−0·1	113	2 08·2	·	·	137	1 52·8	−1·5	+0·3	114	1 47·2	−1·3	−0·5	130
11	4006	0·6	2	12·0	3 23·1	−1·6	+1·1	222	2 53·9	·	·	202	2 58·5	−1·8	+1·5	229	2 40·2	−2·0	+2·4	215
17	364	4·3	1	18·1	3 58·5	−0·2	+1·8	53		H				H				H		
17	364	4·3	2	18·1	4 57·5	−0·8	+1·4	259	4 39·9	−0·5	+1·5	247	4 48·4	−0·4	+1·2	270	4 40·1	−0·2	+1·2	261
18	491	6·2	2	19·1	4 28·7	−0·1	+1·7	244		H				H				H		
18	498	6·2	2	19·1	5 40·8	+0·1	+2·9	199	5 12·0	·	·	174	5 40·1	0·0	+2·2	215	5 27·6	+0·3	+2·4	205
19	667	5·3	2	20·2		N				N			7 23·6	·	·	185		N		
21	991	6·1	2	22·3		S			11 18·3	−2·6	−0·9	298		N				G		
21	995	4·1	1	22·4	10 56·9	−1·9	+0·6	93	10 41·7	−2·4	−0·7	119	10 33·8	−1·3	+1·4	82	10 22·1	−1·3	+0·9	95
21	995	4·1	2	22·4		S			11 52·2	−2·0	+2·9	225	11 54·3	−1·9	+1·0	262	11 39·1	−1·7	+1·8	247
Oct. 7	2802	6·4	1	8·3	2 28·6	·	·	151		N			1 52·1	−2·4	−1·7	132	1 54·5	·	·	149
8	2938	7·3	1	9·3		N				N			1 32·0	·	·	141		N		
9	3105	6·2	1	10·4	5 57·2	−0·7	−0·6	70	5 57·0	−1·3	−0·8	87	5 46·4	−0·9	+0·1	53	5 41·8	−1·3	0·0	63
10	3240	6·6	1	11·3	2 28·0	−2·0	+0·3	87	2 09·9	−2·4	+0·1	100	2 01·7	−1·7	+1·1	77	1 49·0	−1·7	+0·9	86
10	3256	6·2	1	11·4		N				N			5 06·6	−2·9	−2·1	121		G		
10	3275	6·1	1	11·5		H				H				H			8 41·6	−0·9	−1·4	99
17	764	5·0	2	18·6	10 01·8	−1·8	+1·4	232	9 24·5	·	·	197	9 36·5	−1·7	+1·5	241	9 19·0	−1·5	+2·3	227

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						U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Oct.	18	895	5·9	2	19·4	4 12·1	0·0	+1·3	264		H				H				H		
	18	915	4·7	2	19·5	8 41·2	−1·7	+1·2	256	8 15·0	−1·2	+2·2	234	8 19·8	−1·3	+1·1	269	8 07·8	−1·1	+1·4	257
	19	1077	4·1	1	20·6	9 02·6	−1·5	+1·7	70	8 40·4	−1·5	+0·8	93	8 46·2	−0·8	+2·3	58	8 31·9	−0·7	+1·7	72
	19	1077	4·1	2	20·6	10 22·4	−2·1	−0·3	286	10 03·2	−2·1	+1·2	258	9 54·3	−1·9	0·0	293	9 45·2	−1·7	+0·7	277
	20	1193	5·4	2	21·5		N			7 41·7	−1·2	−1·0	318		N				N		
	20	1205	6·3	2	21·6		G			10 51·7	−2·4	−1·1	303		N			10 22·9	−2·1	−2·1	323
Nov.	5	3035	6·8	1	7·5	1 04·3	−2·3	−1·1	107	0 57·1	−3·3	−1·9	123	0 32·9	−2·2	0·0	94		S		
	5	3057	6·7	1	7·6		H				N			4 34·3	−1·3	−1·8	106	4 39·6	−1·9	−2·5	120
	6	3190	3·0	1	8·6	2 36·7	·	·	128		N			2 00·1	−2·4	−0·5	102	1 53·0	−2·9	−0·8	112
	6	3190	3·0	2	8·6	3 11·5	·	·	184		N			3 05·4	−1·0	+1·2	211	2 52·6	−0·9	+2·1	202
	7	3327	6·8	1	9·5	1 16·9	−2·2	+0·1	94	0 59·5	−2·8	−0·2	107	0 48·9	−1·8	+1·0	80		S		
	7	3339	6·7	1	9·6		N			4 45·7	−0·4	+2·0	19		N				N		
	8	3478	6·5	1	10·5	0 19·8	−1·2	+1·8	45		S				S				S		
	15	991	6·1	2	17·6	3 25·6	−0·2	+1·1	272		H				H				H		
	16	1127	5·9	2	18·7	3 53·7	0·0	+1·3	262		H				H				H		
	18	1395	6·3	2	20·9		N			9 10·8	−1·8	−1·4	317		N			8 47·2	−1·6	−2·9	338
	19	1493	6·4	2	21·8	7 34·4	−0·6	+0·7	289	7 22·3	−0·2	+1·3	262	7 28·4	−0·2	+0·5	296		H		
Dec.	4	3288	5·9	1	6·8	0 22·3	−1·6	+0·6	56	0 02·9	−2·2	+0·8	66		S				S		
	4	3303	6·2	1	6·9	3 42·8	−0·6	−0·5	66	3 42·5	−1·2	−0·8	86	3 33·1	−0·8	+0·2	50	3 28·2	−1·2	+0·1	60
	4	3425	4·6	1	7·7	23 46·7	−1·4	+1·5	42		S				S				S		
	5	3434	7·4	1	7·8	2 08·6	−0·9	+1·2	31	1 49·2	−1·5	+1·3	45	1 59·0	−0·2	+3·0	4	1 41·3	−0·8	+2·6	15
	5	3446	7·2	1	7·9	3 31·7	−0·9	0·0	57	3 23·9	−1·6	−0·2	75	3 17·9	−1·0	+0·9	39	3 08·1	−1·4	+0·9	49
	6	25	7·5	1	8·8	1 13·8	−1·3	+1·5	38	0 48·8	−1·7	+1·7	49	0 58·5	−0·8	+2·6	16	0 40·3	−1·0	+2·5	25
	8	306	6·9	1	10·9	3 11·4	·	·	0	2 37·7	−0·9	+2·9	21		N				N		
	13	1077	3·8	1	16·0	4 05·1	·	·	151		N			3 44·7	−0·9	0·0	127	3 43·6	−1·4	−1·5	146
	13	1077	3·8	2	16·0	4 33·8	·	·	198		N			4 30·9	−0·2	+2·9	220	4 12·2	+0·7	+4·3	201
	14	1205	6·3	2	16·9	4 16·5	−0·6	+1·8	253	3 56·0	+0·1	+2·4	229	4 10·6	−0·2	+1·4	265	4 02·2	+0·1	+1·5	252
	17	1576	5·3	2	20·2		S			12 29·5	−3·1	0·0	263	12 08·5	−2·3	−0·4	278	11 55·1	−3·4	+1·6	251
	30	3113	5·4	1	3·1		H				N				H			1 51·6	−1·9	−3·1	126
	31	3256	6·2	1	4·1	1 32·1	0·0	+1·3	20	1 21·7	−0·6	+0·7	42		G			1 21·4	0·0	+2·5	10

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						U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P	U.T.	a	b	P
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Jan.	9	3177	6·0	1	2·5		N			2 08·7	+0·6	+3·2	4		N			·	N ·	·	
	9	3181	5·9	1	2·5		H			2 05·8	−1·3	−1·6	104	1 56·9	−0·9	−0·9	82	1 50·4	−0·7	−0·5	61
	12	66	6·8	1	5·5	1 01·5	−1·8	−0·8	107		N				S				S		
	12	83	6·9	1	5·7		N			5 07·5	−0·7	+0·2	52	5 10·9	−0·4	+1·1	26		N		
	13	210	6·6	1	6·6	2 26·5	−1·0	+0·9	41	2 03·7	−2·2	+0·4	79	2 06·2	−1·6	+0·9	61	2 11·4	−1·1	+1·4	41
	14	364	4·3	1	7·8	7 13·8	−0·3	−2·5	115		N				N			7 22·2	−0·6	−4·6	136
	15	462	5·9	1	8·6	1 41·3	−0·2	+3·4	10		S				S			1 25·9	+0·1	+3·8	7
	15	491	6·2	1	8·8	8 55·3	−0·2	−1·2	78		H			9 12·4	−0·1	−2·3	117	8 58·6	−0·3	−1·6	93
	16	608	6·0	1	9·6	3 32·6	−1·4	+0·6	77	3 21·7	·	·	130	3 13·7	−2·1	+0·1	101	3 14·6	−1·5	+1·0	79
	16	626	6·4	1	9·8	8 22·2	−0·3	−3·1	130		N				N				N		
	16	635	3·9	1	9·9	10 11·8	+0·1	−1·8	105		N				H			10 21·3	+0·1	−2·5	124
	17	741	5·7	1	10·6	1 14·0	−0·9	+1·1	102		N				S				S		
	23	1487	1·3	2	16·6	3 26·6	0·0	+1·4	278		H				H				H		
Feb.	7	3421	5·1	1	2·1		N			2 11·9	−0·5	0·0	55	2 13·6	−0·3	+0·7	31		G		
	9	170	6·2	1	4·1		N			3 06·1	−0·7	+1·6	25		N				N		
	9	178	6·8	1	4·1		N			3 54·5	−0·8	−0·2	65	3 54·2	−0·6	+0·4	41	4 00·6	−0·3	+2·2	9
	10	306	6·9	1	5·1	3 36·8	·	·	3	3 15·0	−1·5	−0·1	69	3 15·4	−1·2	+0·6	47	3 21·6	−0·7	+1·9	18
	11	444	6·2	1	6·1	3 42·4	−1·2	−1·8	104		N				N			3 36·0	−1·7	−2·1	114
	11	453	7·3	1	6·2		N			6 58·0	−0·4	−0·7	74	6 54·9	−0·5	−0·1	53	6 55·8	−0·6	+0·9	26
	12	692	1·1	1	7·9	21 22·2	·	·	359	20 38·1	+0·5	+1·9	43	20 52·8	+0·6	+2·5	25	21 17·7	·	·	353
	12	692	1·1	2	7·9	21 36·9	·	·	330	21 25·8	−0·3	+0·8	285	21 29·6	−0·5	+0·5	303	21 26·1	·	·	336
	13	729	7·2	1	8·2	5 06·0	−1·2	+0·1	58	5 10·5	−2·0	−2·4	119	4 58·3	−1·8	−0·9	94	4 51·9	−1·5	+0·1	70
	13	741	5·7	1	8·3	8 39·3	0·0	−1·9	108		N			9 12·2	·	·	160	8 48·5	0·0	−2·6	127
	14	862	7·5	1	9·2		N			3 53·3	−2·2	+1·5	61	4 05·9	−1·7	+3·2	34		N		
	14	863	6·7	1	9·2		N			4 09·4	−2·3	+1·2	66	4 18·9	−1·9	+2·6	41		N		
	14	871	6·9	1	9·2	5 40·2	−1·3	−0·7	81	6 07·5	·	·	154	5 42·1	−1·8	−2·2	120	5 28·5	−1·6	−0·8	95
	14	886	7·0	1	9·3	8 54·1	0·0	−2·3	121		N				N			9 05·0	+0·1	−3·4	144
	15	1006	6·9	1	10·2	3 29·4	−1·3	+2·9	40	2 49·8	−2·0	+0·6	96	2 55·1	−1·6	+1·5	74	3 06·6	−1·1	+2·6	50
	15	1025	7·4	1	10·3		N			6 51·2	−2·6	+2·0	45		N				N		
	15	1038	6·8	1	10·4	10 19·8	·	·	163		N				N				N		
	16	1130	7·2	1	11·2	3 43·6	−1·3	+2·4	53	3 10·1	−1·9	+0·1	109	3 13·1	−1·5	+1·2	87	3 22·3	−1·1	+2·2	63
	16	1151	6·8	1	11·4		N			9 52·1	−1·4	−0·2	63	9 53·0	·	·	38		N		

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					U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
				d	h m	m	m	o	h m	m	m	o	h m	m	m	o	h m	m	m	o
Feb. 17	1262	6·2	1	12·3	8 24·4	·	·	170		N				N				N		
19	1487	1·3	1	14·4	10 59·5	−1·3	−0·9	68	11 14·5	−1·2	−1·8	113	11 02·5	−1·3	−1·5	100	10 50·3	−1·4	−1·1	88
19	1487	1·3	2	14·4	11 49·3	−0·1	−2·7	335	12 27·6	−0·6	−1·8	295	12 14·0	−0·5	−2·2	307	11 57·0	−0·5	−2·4	318
26	2223	4·0	1	21·5	12 37·8	−1·5	−0·2	106	12 39·8	−1·4	−1·7	147	12 30·5	−1·5	−0·8	133	12 24·2	−1·3	−0·2	121
26	2223	4·0	2	21·5		S			13 55·0	−2·7	+0·1	258	13 51·4	−2·2	−0·4	271	13 44·6	−1·7	−0·4	281
Mar. 11	516	7·3	1	4·6		N			2 28·7	−1·4	+3·2	19		N				N		
11	526	6·9	1	4·7		N			5 21·7	−0·5	−0·7	76	5 18·2	−0·6	−0·2	55	5 18·5	−0·7	+0·8	28
12	667	5·3	1	5·6	1 51·9	−1·3	+0·6	57		S				S				S		
12	672	6·6	1	5·7	2 07·0	−1·4	−1·4	107		S				S				S		
12	677	4·8	1	5·7	3 03·6	−1·2	−2·3	118		N				N			3 01·1	−1·7	−3·8	136
12	680	6·7	1	5·7	3 17·6	−1·0	−3·6	136		N				N				N		
12	685	6·5	1	5·7	4 41·7	−0·6	−2·3	116		N				N			4 46·9	−0·7	−3·8	137
12	692	1·1	1	5·8	5 45·7	−0·3	−1·5	88		N			6 05·3	−0·2	−2·8	128	5 48·4	−0·5	−1·9	105
12	692	1·1	2	5·8	6 45·1	−0·1	−1·3	259		N			6 49·9	−0·6	+0·3	220	6 47·0	−0·4	−0·7	242
13	823	6·6	1	6·8	5 07·4	−0·8	−1·4	90		N			5 23·0	−0·8	−3·1	131	5 04·4	−1·1	−1·8	107
13	829	7·0	1	6·8	6 24·1	−0·2	−2·5	124		N				N			6 35·3	0·0	−4·2	149
13	832	4·7	1	6·8	6 46·8	−0·7	0·0	38	6 56·3	−0·5	−1·4	97	6 47·9	−0·6	−1·0	79	6 40·7	−0·8	−0·6	60
13	836	5·5	1	6·8	7 17·1	−0·4	−0·7	56	7 35·9	−0·1	−1·7	109	7 26·0	−0·3	−1·3	91	7 16·6	−0·5	−1·1	74
16	1236	5·1	1	9·9	7 41·3	−0·5	−2·3	125		N			8 12·5	·	·	169	7 46·5	−0·5	−3·0	145
16	1241	6·4	1	9·9	8 40·6	−0·5	−1·6	93	9 12·8	−0·1	−2·5	138	8 57·6	−0·4	−2·1	122	8 42·4	−0·6	−1·9	109
18	1434	5·6	1	11·7		N				S			2 41·8	−1·1	+4·4	46		N		
18	1449	6·7	1	11·9	7 58·0	−1·2	−1·3	97	8 24·2	−0·9	−2·9	145	8 06·8	−1·2	−2·2	129	7 51·0	−1·4	−1·6	115
18	1466	5·2	1	12·0	·	H	·			H				H			12 13·6	0·0	−1·7	103
27	2448	6·4	2	21·0	11 10·2	−0·6	−1·1	342	11 12·0	−1·8	−0·1	295	11 09·2	−1·3	−0·3	308	11 05·0	−0·9	−0·3	321
28	2591	6·5	2	22·1		S				S			12 52·3	−1·6	−0·7	313	12 44·5	−1·1	−0·7	326
29	2757	5·1	2	23·1		S			12 53·3	−1·9	+0·3	281	12 53·3	−1·6	+0·2	293	12 51·9	−1·2	+0·2	304
Apr. 8	618	7·2	1	3·3		N			4 37·6	−0·5	+0·4	44	4 46·0	·	·	8		N		
10	913	5·2	1	5·3		N			4 43·2	·	·	26		N				N		
11	1060	7·4	1	6·3	4 30·1	−0·4	−3·0	141		N				N				N		
14	1415	6·2	1	9·4		N			7 02·0	−1·7	−0·9	84	6 56·1	−2·0	−0·3	67	6 53·8	·	·	44
14	1487	1·3	1	10·1	21 37·6	−0·2	−0·4	152		N				N				H		
14	1487	1·3	2	10·1	22 15·8	+0·2	+3·1	232		N				N			22 06·8	+0·7	+3·5	221
15	1522	6·8	1	10·5	8 04·7	+0·2	−3·3	172		N				N				N		
25	2697	6·5	2	20·6		H			8 49·3	−1·0	+0·8	279	8 53·1	−0·8	+0·6	294		H		
25	2708	5·9	2	20·6		S			10 53·0	−2·2	+1·1	255	10 56·9	−1·8	+0·8	267	10 58·4	−1·4	+0·7	277
May 7	862	7·5	1	3·0	4 39·5	+0·1	−1·2	81		H			4 56·3	+0·2	−1·7	112	4 45·4	0·0	−1·5	97
7	863	6·7	1	3·0	4 49·6	+0·1	−1·3	83		H				H			4 56·0	+0·1	−1·5	98
8	1025	7·4	1	4·0	5 11·9	−0·1	−1·2	73	5 36·4	+0·3	−1·7	118	5 26·2	0·0	−1·5	103	5 15·7	−0·2	−1·4	89
9	1151	6·8	1	5·1	6 28·3	+0·2	−1·7	111	·	H	·			H			6 38·0	+0·2	−2·0	125
11	1385	6·5	1	7·1		N			7 29·3	−0·5	−0·7	72	7 24·8	−0·8	−0·4	55	7 23·4	·	·	32
12	1487	1·3	1	8·1	6 54·8	+0·1	−2·7	157		N				N			7 10·8	·	·	183
12	1487	1·3	2	8·1	7 37·9	−0·4	−1·2	243		N				N			7 32·4	·	·	220
25	3105	6·2	2	21·2		S			8 51·3	−1·2	+2·7	217		H				H		
25	3126	4·3	1	21·4		S			11 56·1	−2·1	+0·7	85	11 59·4	−1·8	+0·9	73		S		
June 6	1217	6·1	1	3·6		N			3 50·9	−0·6	−1·0	84		S				S		
10	1645	6·6	1	7·6		S				N			4 37·1	−0·1	−3·8	174		S		
10	1648	7·0	1	7·6	5 11·0	−0·8	−1·8	105	5 41·5	−0·7	−2·5	139	5 25·7	−0·9	−2·2	128	5 09·6	−1·0	−1·9	119
14	2072	6·7	1	11·7	7 12·3	−1·3	−0·9	66	7 19·4	−1·8	−1·3	100	7 10·3	−1·8	−1·0	89	7 00·5	−1·7	−0·7	79
19	2759	3·6	1	16·7		N			5 53·0	−1·5	+1·6	71	6 03·3	−1·6	+2·1	55		H		
19	2759	3·6	2	16·7		N			7 02·4	−1·5	0·0	299	7 00·2	−1·1	−0·2	314	6 56·1	−0·6	−0·4	330
21	4006	0·6	2	18·7		N			6 19·8	+0·1	−1·1	325		N				N		
28	508	4·3	1	26·0		S			11 38·8	−0·4	+0·6	110	11 44·7	−0·3	+1·2	95		S		
July 10	1923	7·1	1	8·2		H			6 42·7	−0·7	−1·7	108	6 31·3	−0·8	−1·6	96	6 18·6	−0·8	−1·5	87
12	2128	5·8	1	10·2		S			4 11·0	−2·3	−0·9	108		S				S		
13	2247	5·6	1	11·2		S				N			4 34·0	·	·	170		S		
14	2390	6·7	1	12·2		N			5 06·4	−2·6	+0·5	76	5 08·5	−2·5	+1·0	61	5 11·8	·	·	46
18	4006	0·5	1	16·5		H			13 21·7	−1·1	−2·0	113	13 10·9	−0·7	−1·2	90	13 02·5	−0·5	−0·8	69
21	3478	6·5	2	19·4		S			9 46·1	−1·4	+1·9	223	9 55·5	−1·4	+1·5	237	10 01·9	−1·3	+1·2	249
26	608	6·0	2	24·5		S			10 14·6	+0·2	+1·9	226	10 26·6	0·0	+1·8	240	10 38·5	−0·1	+1·7	253
Aug. 8	2089	6·8	1	7·7		N			5 41·9	−0·9	−0·3	60	5 42·8	·	·	36		N		
10	2341	7·2	1	9·7		H			6 07·1	−1·5	−1·5	105	5 57·0	−1·4	−1·2	92	5 46·3	−1·3	−1·0	82
11	2463	6·9	1	10·7		N			4 58·7	−2·4	+0·7	56	5 03·3	·	·	37		N		
13	2797	3·0	1	12·8	7 26·2	·	·	15	7 08·3	−1·7	+0·4	55	7 10·8	−1·3	+0·8	38	7 17·0	·	·	14
13	2797	3·0	2	12·8		H			8 18·2	−1·8	−1·5	290	8 04·7	−2·0	−2·1	309	7 42·5	·	·	334
17	3419	4·5	1	16·9	9 56·3	−1·3	−0·2	77	9 50·0	−2·9	−1·1	110	9 44·6	−2·0	−0·1	90	9 42·2	−1·4	+0·4	74
17	3419	4·5	2	16·9	11 02·2	−0·8	0·0	232	10 40·3	−0·5	+2·4	192	10 50·0	−1·0	+1·0	215	10 52·1	−1·1	+0·3	234
21	444	6·2	2	21·0		S			11 00·2	−0·5	+3·1	199	11 16·4	−1·0	+2·2	220	11 27·4	−1·1	+1·6	238
27	1275	5·6	2	27·0		S			12 25·9	−0·1	+1·2	266		S				S		
Sept. 3	1950	5·8	1	4·0		S			3 07·6	−0·8	−1·9	116		S				S		
9	2704	5·8	1	10·0	3 05·7	−1·5	+0·1	74	2 50·1	−2·2	0·0	101		S				S		

Date		Z.C. No.	Mag.	Ph.	Age of Moon	J EDMONTON, ALTA. W. 113·075, N. 53·533				K CALIFORNIA W. 120·000, N. 36·000				L OREGON W. 121·000, N. 42·500				M VANCOUVER, B.C. W. 123·100, N. 49·500			
						U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*	U.T.	*a*	*b*	*P*
					d	h m	m	m	°	h m	m	m	°	h m	m	m	°	h m	m	m	°
Sept.	11	4006	0·6	1	12·0	1 54·5	−0·9	+1·1	94	1 36·0	−0·6	−0·3	132	1 36·9	−0·7	+0·6	116	1 41·6	−0·7	+1·1	104
	11	4006	0·6	2	12·0	3 02·2	−1·2	+1·0	250	2 24·4	−1·8	+2·5	217	2 36·4	−1·5	+1·8	233	2 44·9	−1·2	+1·5	244
	17	364	4·3	2	18·1	5 00·6	−0·4	+1·1	301		H				H				H		
	17	405	4·4	1	18·4		S			12 57·4	−2·0	−1·3	100	12 51·0	−1·6	−0·2	76	12 49·2	−1·2	+0·5	53
	18	498	6·2	2	19·1	6 06·4	−0·1	+1·8	244		H				H			5 59·1	+0·1	+1·7	245
	18	508	4·3	1	19·2	6 46·7	−0·6	+1·4	100	6 29·5	·	·	136	6 30·1	−0·5	+0·8	113	6 37·0	−0·3	+1·3	98
	18	508	4·3	2	19·2	7 39·1	−0·3	+2·2	218	6 51·6	·	·	181	7 11·9	+0·1	+2·6	205	7 28·0	−0·2	+2·1	221
	19	667	5·3	2	20·2	8 00·1	−0·3	+2·1	232	7 19·3	+0·5	+2·9	200	7 35·6	+0·1	+2·2	219	7 50·2	−0·1	+2·0	234
	21	995	4·1	1	22·4	10 58·6	−0·3	+3·5	31	10 13·8	−0·6	+1·5	76	10 25·4	−0·4	+2·2	57	10 43·2	−0·1	+3·2	34
	21	995	4·1	2	22·4	11 42·4	−1·6	−1·0	316	11 25·6	−1·3	+1·2	264	11 30·4	−1·4	+0·6	285	11 28·9	−1·5	−0·3	311
	22	1127	5·9	2	23·4		N			12 51·8	·	·	325		N				N		
Oct.	9	3105	6·2	1	10·4		G			5 28·7	−1·2	+0·9	42	5 35·0	−0·6	+1·4	22		N		
	9	3115	6·3	1	10·5		H				G			7 00·4	−1·6	−1·8	110	6 48·0	−1·2	−1·0	88
	10	3240	6·6	1	11·3	2 08·5	−1·0	+1·4	55		S				S				S		
	10	3256	6·2	1	11·4	4 42·9	−1·4	+0·1	79	4 29·8	−2·5	−0·3	105	4 27·8	−1·9	+0·3	90	4 27·3	−1·5	+0·6	77
	10	3275	6·1	1	11·5		H			8 29·3	−1·0	−0·7	78	8 25·7	−0·7	−0·2	58	8 24·5	−0·4	+0·2	35
	11	3419	4·5	1	12·5	7 44·1	−1·1	−0·9	84		N			7 43·7	−2·0	−1·4	104	7 34·4	−1·4	−0·5	82
	17	764	5·0	2	18·6	9 32·5	−1·5	0·0	290	9 07·2	−1·4	+1·6	247	9 14·4	−1·5	+1·0	266	9 16·5	−1·5	+0·4	288
	18	913	5·2	2	19·5	8 01·1	−0·2	+2·8	217		N			7 24·1	·	·	183	7 49·6	+0·1	+2·6	217
	18	915	4·7	2	19·5	8 13·5	·	·	325	7 59·8	−0·8	+0·9	276	8 03·7	−1·0	+0·5	296	8 01·3	·	·	325
	19	1077	4·1	1	20·6		N			8 31·1	−0·1	+2·3	52	8 50·2	+0·3	+3·9	26		N		
	19	1077	4·1	2	20·6		N			9 29·4	−1·4	+0·2	295	9 25·4	−1·8	−1·3	323		N		
	21	1331	Var	2	22·7	12 06·5	−1·2	+1·9	251		N				N			11 46·4	−0·8	+2·8	238
	21	1335	6·3	2	22·7		S				N				N			12 48·7	−1·3	+3·1	233
Nov.	5	3055	7·1	1	7·6	3 29·5	−1·5	−1·5	114		N			3 34·0	·	·	133	3 17·7	−1·8	−1·0	110
	5	3057	6·7	1	7·6		H			4 16·0	−1·8	−1·0	94	4 09·5	−1·4	−0·6	77	4 04·1	−1·1	−0·3	60
	6	3190	3·0	1	8·6	1 47·2	−1·4	+0·5	73	1 25·1	−2·2	+0·4	95	1 27·3	−1·8	+0·8	82	1 30·2	−1·4	+1·0	72
	6	3190	3·0	2	8·6	3 01·1	−1·2	0·0	248	2 40·9	−1·7	+1·3	224	2 45·8	−1·6	+0·8	238	2 46·4	−1·5	+0·4	251
	6	3210	7·0	1	8·7		H			6 29·5	−1·1	−1·1	89	6 23·4	−0·8	−0·6	68	6 19·4	−0·5	−0·2	47
	7	3327	6·8	1	9·5	0 55·2	−1·0	+1·4	57		S				S				S		
	8	3478	6·5	1	10·5	0 32·9	·	·	3		S				S				S		
	8	3506	6·3	1	10·7	7 21·3	−1·1	−1·9	105		N				N			7 15·7	−1·6	−1·8	107
	15	995	4·1	2	17·6	4 06·0	+0·2	+1·7	250		H				H				H		
	16	1171	6·3	2	19·0		N			13 28·5	−1·8	−1·8	297	13 12·1	−1·4	−2·9	320		N		
Dec	4	3303	6·2	1	6·9		N			3 16·6	−1·1	+1·0	38	3 24·4	−0·4	+1·7	16		N		
	4	3428	5·2	1	7·8	23 49·3	−1·5	+0·6	116		S				S				S		
	5	3446	7·2	1	7·9		N			2 57·2	−1·0	+2·0	24	3 12·7	·	·	359		N		
	9	444	6·2	1	11·8	1 17·3	−0·7	+1·2	106		N				S			1 06·2	−0·5	+1·2	103
	9	462	5·9	1	12·0	6 42·8	−1·7	−2·1	119		N				N			6 31·5	−2·4	−2·3	126
	13	1077	3·8	1	16·0	3 54·7	−0·2	+1·6	84	3 35·0	−0·3	+0·3	119	3 39·3	−0·1	+1·0	101	3 47·9	0·0	+1·4	84
	13	1077	3·8	2	16·0	4 55·3	−0·5	+1·5	267	4 21·5	+0·2	+2·2	228	4 34·4	−0·1	+1·8	248	4 45·3	−0·3	+1·5	266
	13	1113	5·2	2	16·3	14 06·7	−0·3	−1·8	288		S			14 18·4	−0·8	−0·9	255	14 08·8	−0·7	−1·4	270
	14	1205	6·3	2	16·9	4 21·6	−0·4	+0·6	309		H				H			4 16·4	−0·2	+0·5	308
	17	1576	5·3	2	20·2	11 45·3	−1·2	−0·8	309	11 24·1	·	·	241	11 33·1	−2·1	+0·9	268	11 32·8	−1·5	+0·2	289
	30	3113	5·4	1	3·1		H			1 28·7	−1·7	−1·2	97	1 21·3	−1·2	−0·7	78	1 15·5	−0·9	−0·4	60

How to Use the Prediction Tables

Universal time is Greenwich time, counted from 0 to 24 hours, beginning at midnight; times greater than 12:00 are p.m. To convert to standard times in the United States and Canada, subtract the following number of hours: for AST, 4; EST, 5; CST, 6; MST, 7; and for PST, 8. If necessary, add 24 hours to the UT before subtracting, and use the previous calendar date.

Consider, for an example, the last line of the table, December 30, 1962, for the star Z.C. 3113. (The table on the first page of the supplement identifies this star also as 30 Capricorni.) The next column shows that the occultation occurs too near the horizon to be observed at Edmonton.

For the California station, **K** (LoS +120°.000, LS +36°.000), the disappearance takes place at 1:28:7 UT, corresponding to 5:28.7 p.m. Pacific standard time on December 29th.

Suppose an observer is in Berkeley, California, Lo +122°.262, L + 37°.873. The **a** quantity for **K** is −1.7 and **b** is −1.2. Hence the correction to the standard-station time is −1.7(122.3 − 120.0) − 1.2(37.9 − 36.0) = −6.2 minutes, giving 5:22.5 p.m. PST on the 29th for Berkeley.

The table also tells that at station **K** the star's place of disappearance on the moon's edge will be 97° from the north point, counted eastward around the limb.

Mrs. Sadler points out that an observer located between two standard stations can often make more accurate predictions by replacing the **a** and **b** of the nearer station by **a′** and **b′**, found as follows. First compute the interpolation factor **q**:

$$\mathbf{q} = \frac{\mathrm{L} - \mathrm{LS}_1}{2(\mathrm{LS}_2 - \mathrm{LS}_1)},$$

where the subscripts 1 and 2 indicate the nearer and farther standard station, respectively. Then **a′** and **b′** are given by:

$$\mathbf{a'} = \mathbf{a}_1 + \mathbf{q}(\mathbf{a}_2 - \mathbf{a}_1),$$
$$\mathbf{b'} = \mathbf{b}_1 + \mathbf{q}(\mathbf{b}_2 - \mathbf{b}_1).$$

For example, an observer at Norman, Oklahoma (Lo +97°.4, L +35°.2), is nearer station **G** (LoS_1 +98°.0, LS_1 +31°.0) than station **H** (LoS_2 +104°.9, LS_2 +39°.7). He would find

$$\mathbf{q} = \frac{35.2 - 31.0}{2(39.7 - 31.0)} = +0.24.$$

New factors may then be formed for all occultations listed for both **G** and **H**. Thus, in the case of Z.C. 170 on February 9th:

$$\mathbf{a'} = -0.5 + 0.24(-0.4 + 0.5) = -0.5,$$
$$\mathbf{b'} = +0.1 + 0.24(+1.7 - 0.1) = +0.5.$$

Then **a′** and **b′** can be used, just as **a** and **b** in the previous example.

DEEP-SKY WONDERS

THE PART of the constellation Aquarius that most amateurs know best is the Water Jar. Here three stars — Gamma, Eta, and Pi Aquarii — make a bright, nearly equilateral triangle enclosing a central star of comparable luster. In this dim region of the heavens it is the most obvious naked-eye configuration. Zeta, the central star, is an interesting double resolvable in most amateur telescopes.

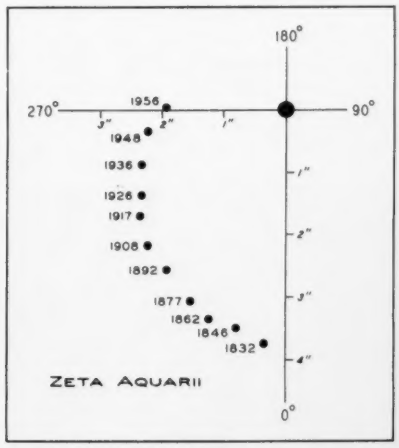
Its two visible components have magnitudes of 4.4 and 4.6. Currently they are slightly less than two seconds of arc apart and gradually drawing closer together. A century ago, Zeta Aquarii was an easy pair even in very small telescopes, but a 3-inch refractor may be required today. Reflectors with central diagonals will probably need an inch more aperture.

Though discovered to be a double almost 200 years ago, Zeta was first measured accurately in the 1820's, when the companion was due north of the primary star and about 4″ distant. Since then, as the diagram shows, the secondary (B) star has moved to the west of the primary (A), with less than 2″ between them.

Because the position angle has changed by only about 90° since the first reliable measurements were made, the orbit is still rather uncertain. In 1941, K. A. Strand derived a period of 400 years, and about a decade ago W. Rabe found 361 years, but the latest study by O. Franz gives 600. At present the pair is nearly at its minimum separation, periastron being due in 1972, according to Franz.

The B component has an unseen companion, whose presence is revealed by an undulation in the path of B around A. This third body, discovered by Strand, has a period of 25.5 years.

At the present time, Zeta's visible components are 1″.84 apart. An interesting amateur experiment is to determine the minimum telescope aperture with which this pair can be resolved. Cut a series of cardboard screens, with circular holes of different diameters, to place over the front end of the telescope. If used with a reflector, the holes should be offset. By looking at Zeta through one screen after another, the smallest aperture that splits the pair can be found.



Orbital motion of star B relative to A in the Zeta Aquarii system.

As was discussed on page 101 of the February issue, the resolving power of a telescope depends upon the difference in brightness of the stars, as well as on their separation. The list of doubles on page 262 of this month's issue contains many suitable test objects. A very careful amateur study of the visibility of faint companions was reported by H. H. Peterson in SKY AND TELESCOPE for September, 1954.

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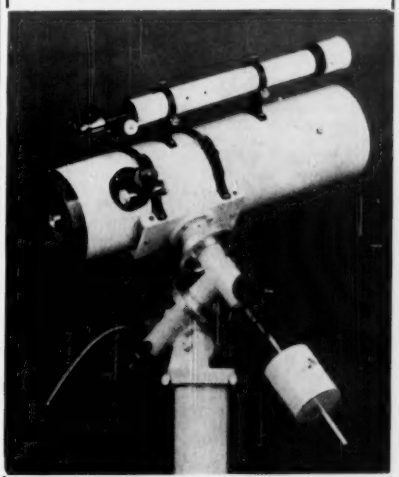

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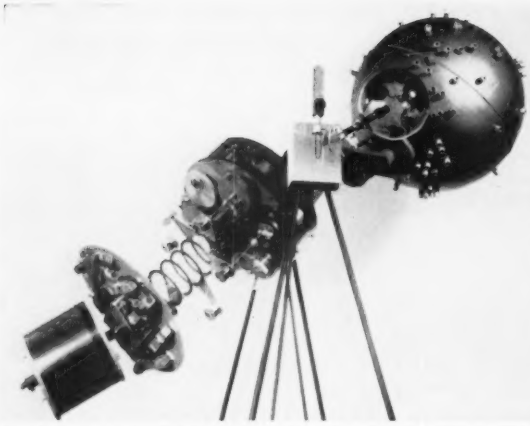

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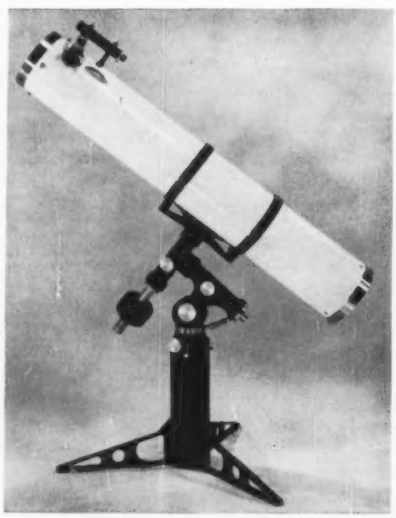

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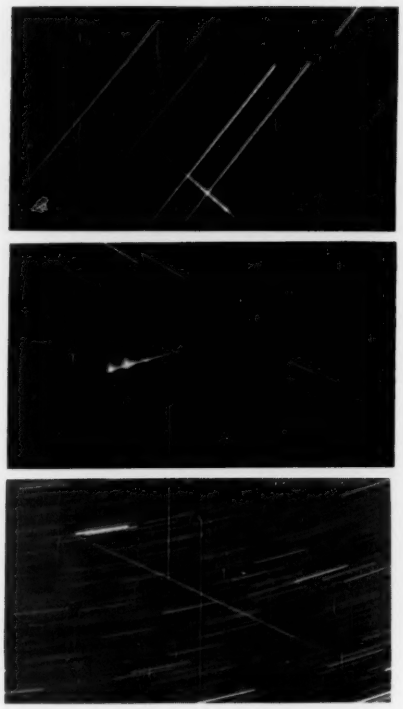

Three of Norman D. Petersen's photographs of Perseid meteors. The first and second, also visually observed, were in Taurus and Camelopardalis, respectively, and the last was in Cygnus.

PHOTOGRAPHING THE PERSEIDS

DURING the 1961 Perseid meteor shower, early on the mornings of August 12th and 13th I used my 35-mm. Minolta camera with a wide-angle lens to obtain the accompanying meteor photographs. These are three of the 19 meteors recorded on 33 exposures.

I observed from an altitude of 5,000 feet in the Angeles National Forest, above Palmdale, California. The sky was superb on both nights — 6th-magnitude stars were visible even near the horizon. Temperatures in the middle 60's made the sessions comfortable.

To minimize fogging of the film (Kodak Tri-X), I keep my exposures to less than half an hour, and rarely attempt to work in the presence of moonlight. All of these films were developed in Microdol-X for eight minutes at 75 degrees Fahrenheit. The first picture was exposed for 21 minutes, from 8:42 to 9:03 Universal time on the 12th. The meteor was a fast, blue-white object of magnitude −1.

A 10-minute exposure started at 10:19 caught the meteor in the second picture. Also of magnitude −1, it was yellow and traveled with medium speed. The last photograph, from 5:55 to 6:08 UT on the next night, shows a meteor not observed visually, but which I estimated from the negative as magnitude 0.

In all, I counted 309 meteors in 10 hours of observing on the two nights. The most striking was a blue-white object as bright as Jupiter that I followed

for some 20 degrees across the sky. It left a train lasting for 15 seconds.

I am a member of the American Meteor Society and would appreciate hearing from other amateurs who have tried meteor photography.

NORMAN D. PETERSEN
3080 Menlo Dr.
Glendale 8, Calif.

TWO PLANETS AND THE MOON

A BEAUTIFUL configuration of the two inner planets and a thin crescent moon will greet before-dawn risers on Monday, November 6th, when the three objects will be within the same binocular field of view. The scene will also include 1st-magnitude Spica. A properly exposed photograph would record the horizon silhouetted against the dawn sky, the lunar crescent and its earthlit disk, brilliant Venus, reddish Mercury, and possibly the star.

Although at the beginning of November Venus is about 5° west of Mercury along the ecliptic, the brighter planet quickly closes the gap. On the 6th, Mercury can be unmistakably identified to the left and below Venus as they rise nearly together, separated by only 1¼°. Spica, rising about the same time, is 4° to the south.

That morning the moon, two days before new phase, will precede the planets by about half an hour, rising at a point some 5° south of east on the horizon. Venus and Mercury will come up another 5° or so to the south. (These figures depend on the observer's latitude, the distances from the east point being larger for locations north of 40°.) As they rise into the brightening sky, the moon and planets will form a long thin triangle, which will shorten as the moon moves rapidly toward conjunction.

Venus will continue to aid in finding Mercury well into November.

SUNSPOT NUMBERS

The following American sunspot numbers for August have been derived by Dr. Sarah J. Hill, Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

August 1, 20; **2,** 16; **3,** 17; **4,** 8; **5,** 1; **6,** 0; **7,** 5; **8,** 21; **9,** 42; **10,** 62; **11,** 88; **12,** 80; **13,** 82; **14,** 89; **15,** 99; **16,** 86; **17,** 78; **18,** 48; **19,** 46; **20,** 35; **21,** 30; **22,** 23; **23,** 21; **24,** 32; **25,** 35; **26,** 37; **27,** 32; **28,** 28; **29,** 47; **30,** 46; **31,** 47. Mean for August, 42.0.

Below are provisional mean relative sunspot numbers for September by Dr. M. Waldmeier, director of Zurich Observatory, from observations there and at its stations in Locarno and Arosa.

September 1, 51; **2,** 53; **3,** 54; **4,** 55; **5,** 55; **6,** 57; **7,** 51; **8,** 33; **9,** 45; **10,** 57; **11,** 62; **12,** 68; **13,** 89; **14,** 109; **15,** 114; **16,** 102; **17,** 84; **18,** 73; **19,** 70; **20,** 46; **21,** 41; **22,** 40; **23,** 43; **24,** 74; **25,** 83; **26,** 74; **27,** 67; **28,** 69; **29,** 58; **30,** 52. Mean for September, 64.3.

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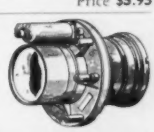

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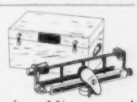

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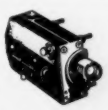

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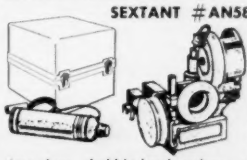

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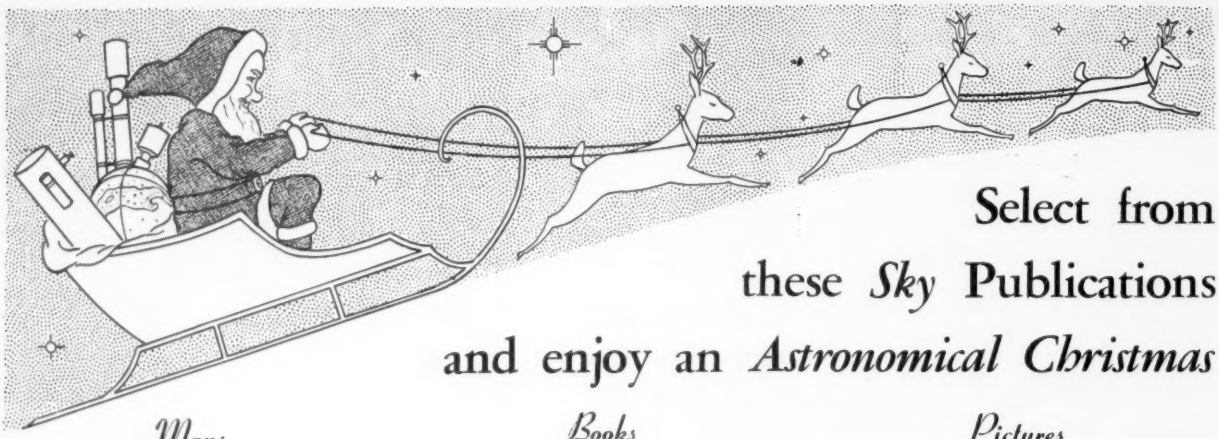

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The Lunik III Reconnaissance

On October 4, 1959, the Soviet Union successfully launched its third space probe, Lunik III, into orbit around the moon. Carrying a battery of intricate scientific equipment, including photographic and television systems, it passed near the moon, getting a first view of the part of the lunar surface that is perpetually hidden from our earth. On command it photographed the moon's far side for 40 minutes, and these images were later telecast to the earth.

The results of this achievement were compiled and edited for the U. S. S. R. Academy of Sciences by three Soviet astronomers, N. N. Barabashov, Kharkov University Observatory, A. A. Mikhailov, Pulkovo Observatory, and Yu. N. Lipsky, Sternberg Astronomical Institute. Dr. Lipsky summarized this work in SKY AND TELESCOPE for March, 1961, page 133. Now the complete Russian **Atlas of the Opposite Side of the Moon,** translated into English by Richard B. Rodman of Harvard Observatory, has been published jointly by Interscience Publishers, Inc., and Sky Publishing Corporation.

This English edition contains every fact, every illustration, in the Russian original. It includes an introduction, "The Photographs and Their Transmission," "Interpretive Techniques," "The Photometric Cross Sections," "Reduction of the Material," and replicas of all 20 full-page plates with their 30 halftone pictures of hitherto invisible lunar features. These pictures have been obtained by means of electronic filtration processes from the best original negatives taken by Lunik III. A major part of the book is the detailed catalogue identifying and describing 498 lunar formations. The definitive map is given in two forms — both as four full pages in the book, and as a 17-by-24-inch folding sheet. 200 pages (8⅜ by 11⅞ inches), 20 plates.

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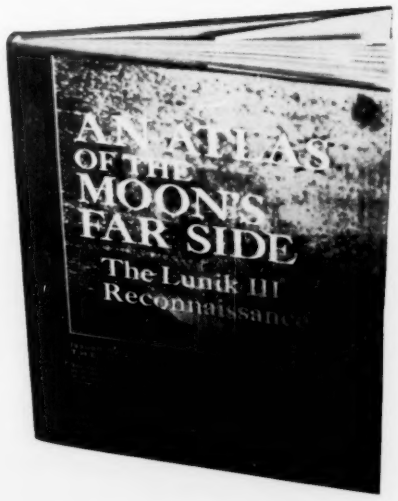

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BOOKS AND THE SKY

GALAXIES

Harlow Shapley. Harvard University Press, Cambridge, Mass., 1961. 186 pages. $5.00.

THE ERA of galaxies may fairly be dated from 1924, when E. P. Hubble first discovered Cepheid variables in the Andromeda spiral. Although daring speculation goes back as far as Thomas Wright in 1750, only since 1924 has it been beyond dispute that most of the Herschel-Dreyer objects are outside our own galaxy and are stellar systems akin to our own. When the era of galaxies was nearly 20 years old, in 1943, Shapley's first edition of *Galaxies* was published as one of the Harvard Books on Astronomy. Now, when the era is nearly twice as old and verging on 40, a welcome revised edition appears.

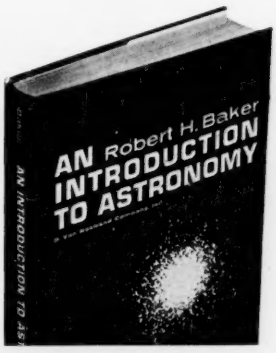
The author comments in his preface that it "would be possible to double the size of this volume by including a fuller report on investigations in current progress, and by going deeper into technical details." Actually, the length of the revised book very nearly equals that of the original. And the organization closely follows the earlier pattern. The chief changes are a fresh and handsome format, a wealth of beautiful new pictures, and a considerable number of brief notices concerning recent research on galaxies.

The introduction sets the stage with some history, a number of compact definitions of astronomical terms, and a description of galaxy types. The next two chapters are devoted to the Clouds of Magellan, our two satellite galaxies some 160,000 light-years away. Their general features are described, along with their Cepheid variables. Miss H. Leavitt's story is nicely retold, including a diagram of her original period-magnitude plot. Of course, the author has been a major contributor to this particular subject and to many others in the realm of the galaxies. Two items of unfinished business are noted: One is the interpretation of the high abundance of short-period Cepheids in the Small Cloud as compared with the Large Cloud and the Milky Way; the other is the dependence of average Cepheid period on location in the Small Cloud.

Next we look at our home galaxy. Here is the exciting but modestly told story of one of the major conceptual revolutions in astronomy — the jump from the heliocentric to the galactocentric hypothesis. I say modestly told because it was Harlow Shapley who, in 1917, made the bold analysis of the spatial distribution of globular clusters that showed how eccentrically located we are in the Milky Way system. Before that time the unknown interstellar dust misguided us into thinking we were near the center of the universe, much as a pea-soup fog makes each observer seem at the center of a little world. Harlow Shapley put us in our place.

Chapter 5 discusses the neighboring galaxies — those within two million light-years. These range from dominant Messier 31 down to dwarf systems like those in Sculptor and Fornax. The metagalaxy and its general structure are considered next. The author describes the very useful Shapley-Ames census of bright galaxies and includes two informative plots of their surface distribution. The Virgo cluster and Fornax group are dealt with in some detail, and we then move on to some results from deeper surveys at Harvard, Mount Wilson, and Lick observatories.

The seventh and final chapter is called "The Expanding Universe," and its first concern is with the distribution of galaxies in space. Although clustering is widespread, the deeper surveys seem to suggest that the observable universe at large is statistically isotropic. Transverse and radial density gradients have been announced many times, but their real significance remains to be seen. As the author says, "Obviously we are not through with this business." Motions of galaxies are then summarized: the null result from proper-motion studies and the spectacular correlation of red shift with apparent magnitude. The book ends with a discussion of alternative interpretations



Robert H. Baker's *Introduction to Astronomy* is the shorter of the renowned Baker texts, intended for one-semester courses. Its Sixth Edition maintains a fine tradition: succinct, accurate, abreast of the latest developments — and eminently teachable. *1961, 376 pages, $5.50.*

Dr. Baker's longer book, *Astronomy*, is the preferred text for full-year courses. Clear narrative, meaningful illustrations, and perceptive choice of topics mark the widely adopted Seventh Edition. *1959, 547 pages, $6.95*

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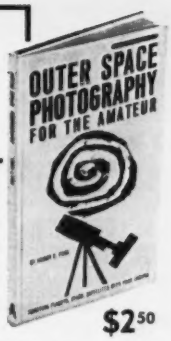

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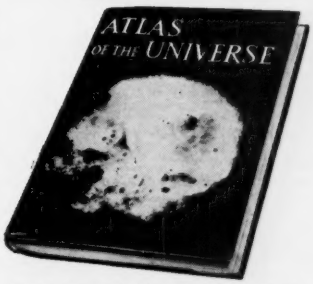

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of the red shift and of possible courses of evolution for individual galaxies.

Apart from a few minor misprints, the revised edition of *Galaxies* is sound on details. The calculations have all been redone on the basis of a 1.5-magnitude boost of the period-luminosity curve for Cepheids. Also adopted is the presently agreeable value of 100 kilometers per second per megaparsec for the Hubble parameter. The writing is brisk and well paced throughout. Here and there anthropocentrism enlivens or diverts, depending on one's taste. The far-out globular cluster prosaically labeled NGC 2419 is the "intergalactic tramp," and the Magellanic Clouds are "astronomical toolhouses of great merit." Notwithstanding a popular tone, the content suits the student in a second college course and the well-read amateur astronomer rather than the man in the street.

From a more general view, the excellence of the book is slightly impaired in two ways. The title *Galaxies* holds out promise of a balanced consideration of all phases of the subject, whereas the book emphasizes the important but not all-inclusive Harvard explorations. The jacket indicates that the revised edition "recounts the advances that have been made in this important subject in recent years." Indeed, the author refers many times to current work, but it seems a pity not to have included a few sections on fresh contributions to our over-all understanding.

For example, radio studies of the gas content of several galaxy types suggest a new and significant scheme of classification. And the current picture of a galaxy's evolution warrants review: development from all gas to chiefly stars, with feedback by some stars so that there is always some interstellar material, even in the elliptical systems.

Yet, Dr. Shapley's book informs and makes fine reading. It ought to be within arm's reach of every student of galaxies.

STANLEY P. WYATT
University of Illinois Observatory

THE TELESCOPE AND THE WORLD OF ASTRONOMY

Marvin F. Riemer. Scope Instrument Corp., Mamaroneck, N. Y., 1961. 211 pages. $3.95.

"IMPATIENT" describes a person with his first telescope; he wants to see everything in the sky in one evening. But a selection of objects must be made, for only part of the celestial sphere is visible at one time, and there are limitations of seeing, transparency, town lights, and instrument aperture. *The Telescope and the World of Astronomy* guides the beginning sky watcher in his first observations.

There is always a question whether a person should read and then observe or vice versa. Marvin Reimer's book permits either approach, combining factual material with lists of celestial objects for study. I have always felt that an evening of observing should include viewing at least one of each type of object, and the author has introduced this nicely in his "work program." This program, however, could have been greatly enlarged, so as to guide the amateur to the point where his knowledge of the sky is sufficient to create individual observing projects.

I read through the book several times and am still amazed at the amount of information the author has included. There is an introduction to every phase of amateur astronomy, and sky watchers should be familiar with them all. For the beginner, Mr. Riemer's bibliographical suggestions of books, maps, and atlases should be taken up only after his own book is exhausted.

Some day an author will include an extra-wide-field photograph of the sky side by side with the corresponding constellation diagram. Mr. Riemer's constellation-study section would have been an excellent place for this.

The warning, "Do not look at the sun directly with a telescope," could have been more emphatic; it cannot be overstressed for any beginner in solar observing.

I did not check the tables, figures, and diagrams for technical accuracy except to scan for gross errors, finding none. Astronomical data vary, depending upon

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the sources an author uses, but by an amount too small to bother the amateur. In the coming exploration of the solar system by interplanetary probes, some questions of distance, size, mass, temperature, composition, and atmosphere will have better answers.

In *The Telescope and the World of Astronomy*, Mr. Riemer has done an excellent job of outlining amateur astronomy, and I do not hesitate to recommend this book to any beginning observer.

WALTER J. KRUMM
San Jose Amateur Astronomers

SURFACE OF THE MOON

V. A. Firsoff. Hutchinson and Co. Ltd., 178 Great Portland St., London W.1, England. 128 pages. 21s.

WITH the turn of the century, interest in the moon's topography began to wane. This decrease was induced partly by great advances in spectroscopy and photography, which diverted astronomical research from solar system to stellar problems, and by the growing belief among astronomers that the moon was a dead, atmosphereless, and unchanging world where nothing ever happened. Except by a few dedicated devotees, our satellite was largely neglected for half a century.

It is true that a number of popular books on the moon appeared in recent years, but most of these devoted little space to actual surface conditions or to how the lunar formations came into being. Among the few writers considering these problems were J. E. Spurr, who endeavored to explain lunar formations in terms of terrestrial geology, and R. B. Baldwin, who attributed the surface features to meteoritic bombardment. They greatly enlarged upon hypotheses that are almost as old as selenology itself, yet their efforts failed to fill many of the major gaps in our understanding of the subject.

The situation has changed with dramatic suddenness. The last decade has seen tremendous interest in lunar problems, due primarily to great advances in the rocket sciences. Recent evidence was obtained by D. Alter and by N. Kozyrev that vulcanism of a low order may still be occurring. And with the strong probability that man himself may set foot on the moon in a few years, lunar geology becomes of prime importance, as does a knowledge of surface conditions.

Much information has been obtained by direct observation and measurement; for example, we now know that most lunar features have comparatively gentle slopes and contours, in contrast to the popular conception of rugged craters and steeplelike mountains. Yet we know little about the small-scale details of these features or the nature of the surface itself. Radio waves emitted by the moon and polarimetric measures of its reflected light indicate that dust may exist on the surface, but how much is as yet unknown.

Will our first lunar astronauts step from their ship onto firm ground or find some sort of "snowshoe" necessary?

Mr. Firsoff is an internationally known lunar student, whose previous book, *Face of the Moon*, was an attempt to deal with some of the major problems of lunar physics. *Surface of the Moon* is a natural sequel, concerned primarily with more specific questions.

The book is divided into three parts. The first is a comprehensive survey of the general structure of the surface, in three major categories: craters, mountains, and maria. The special characteristics of each are discussed at length. Other tectonic features, such as grid lines, faults, crater and mountain chains, are also described.

Part Two deals more specifically with origin problems. While Mr. Firsoff concedes that some lunar features are unquestionably the result of meteoritic impact, he believes this theory becomes untenable as an explanation of many types of major details. Of special interest is his conclusion that Mare Imbrium, often cited as the grave of a small asteroid, could not have been formed in this manner. Objections to the formation of craters by impact are stated; the author maintains that these features more probably resulted from tide-induced welling up and subsidence of subterranean magmas.

Strong resemblances are described between certain lunar craters and terrestrial calderas and shield volcanoes. It will doubtless surprise many readers to learn that subsidence features of large size exist on the earth. One, a laccolithic-type intrusion and withdrawal in the extensive African shield, has a diameter of over 200 miles, and is thus larger than such lunar features as Bailly and Mare Orientalis. By comparison, known impact craters on the earth are small.

Part Three is concerned with the overall results of plutonic forces. Mr. Firsoff elaborates on our moon as a captured body, an idea recently revived with some success by Dr. Alter, who has shown that before the moon's orbit around Earth became stable, high crustal tides produced near perigee passages would be more than sufficient to account for the formation of the lunar surface features. Such tidal action, because it varies with the inverse cube of distance, would be much stronger on the moon's near side than on its far hemisphere. This suggests that certain features, such as the maria, which supposedly were formed by upsurges of interior magmas during near approaches, should be more prevalent on the near side. The recent photographs obtained by Lunik III apparently confirm this uneven distribution. Also of interest is the suggested relationship of the lunar grid systems to the poles of rotation. Mr. Firsoff shows that there are at least three grid systems, from which it may be inferred that the polar axis of the moon has changed position several times.

Surface of the Moon contains a chart of the lunar tectonic grids and several photographs of selected limb regions that were produced by spherical projection. Also included are pictures of terrestrial volcanic formations that strongly resemble certain lunar features. For those who wish to extend their reading, a bibliography lists 102 references.

Some assumptions made by the author may be premature, for example his suggestion that radial bands may be composed of chains of dark-haloed craterlets. If this is true, it becomes most difficult to explain the bright bands in such craters as Anaxagoras and Ramsden, apparently analogous to the radial bands in other craters in every respect except color. We should also be extremely wary of attempts to demonstrate large-scale lunar phenomena by small-scale laboratory experiments: if such comparisons were really valid it would be a simple matter to prove that lunar craters were formed in half a dozen different ways!

Mr. Firsoff is a versatile writer who throws off ideas like sparks. With the impact theory of crater formation currently in much favor, *Surface of the Moon* will doubtless prove to be a very controversial book. It is recommended reading, not only for those who wish to examine nonmeteoritic views of lunar feature formation, but for all serious students of the moon.

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NEW BOOKS RECEIVED

DER WELTRAUM, *Huberta von Bronsart,* 1960, *Verlag Hallwag,* Spittlerstrasse 8, Stuttgart 13, West Germany. 96 pages. DM 4.40.

An amateur may profitably practice his German with this concise pocket-sized summary of astronomy. *The Universe* contains among its numerous illustrations several Palomar Observatory color photographs of celestial objects.

AN ATLAS OF THE MOON'S FAR SIDE, *N. P. Barabashov, A. A. Mikhailov,* and *Yu. N. Lipsky,* editors, 1961, *Interscience* and *Sky.* 167 pages. $7.00.

Late in 1960 the U. S. S. R. Academy of Sciences published a detailed report of the Lunik-III photographs of the reverse side of the moon, together with large-scale maps, a catalogue of newly discovered craters, seas, and mountains, and 30 of the photographs. All of this material is made available to the English-speaking reader in a translation by Richard B. Rodman, of Harvard Observatory.

ADVANCES IN SPACE SCIENCE AND TECHNOLOGY, Vol. 3, *Frederick I. Ordway, III,* editor, 1961, *Academic.* 482 pages. $14.00.

Summaries of present knowledge and possible explorations of the moon, Venus, Mars, and other solar system members make up more than half of this collaborative book by 11 authors. Other chapters cover structural problems of spacecraft, advanced propulsion systems, and weightlessness.

WHEN I GO TO THE MOON, *Claudia Lewis,* 1961, *Macmillan.* 28 pages. $3.00.

For very young children, colorful pictures and brief simple wording implant the idea of the moon as a neighboring world in space.

THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC FOR THE YEAR 1963, *Nautical Almanac Office,* U. S. Naval Observatory, 1961, *U. S. Government Printing Office,* Washington 25, D. C. 518 pages. $4.00.

This standard reference work for astronomers is identical in plan with the preceding volume. Precise ephemerides for the sun, moon, planets, and the first four asteroids, and much other valuable information make this work indispensable to the serious observer. Conversion tables and full explanations of the contents facilitate use. Of wide interest is the day-by-day listing of astronomical phenomena.

BASIC PHYSICS OF THE SOLAR SYSTEM, *V. M. Blanco* and *S. W. McCuskey,* 1961, *Addison-Wesley.* 307 pages. $7.50.

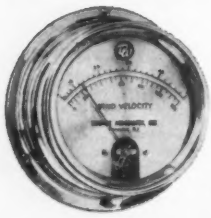
Two astronomers from Case Institute of Technology explain the main properties of solar system bodies, astronomical co-ordinate systems, and the working methods of celestial mechanics. This textbook presupposes some college background in mathematics and physics.

INTRODUCTION TO ASTRONOMY, *Dean B. McLaughlin,* 1961, *Houghton Mifflin.* 463 pages. $7.50.

Written by a University of Michigan astronomer, this textbook is for introductory college courses. The text is nearly equally divided between the solar system and stars.

CORRECTION

In the third column on page 210 in the October issue, the last sentence of the first complete paragraph should end, ". . . there may be small discrepancies between predicted and observed times."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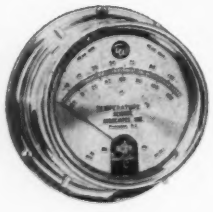
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Wind instruments employ a 7-conductor, low-voltage cable to connect anemometer and wind vane on roof to indoor indicators. Temperature and humidity units are exposed outdoors in special shields and connected by 5-conductor cables to indoor indicators. Instruments may be as far as 200 feet from indicators. Greater distances with special factory calibration. Barometer is self-contained and requires no outside connection.

All instruments except the barometer will operate on 115-volt electric current. ON-OFF switch provided for intermittent operation.

Instruments are complete with all accessories, ready for operation. 60-foot cable provided, as well as mast for wind instruments and shields for temperature and humidity sensors. Cases available in brass finish or polished chrome.

#410 WIND SPEED SYSTEM	$ 64.50
#310 ANEROID BAROMETER	$ 49.50
#411 WIND DIRECTION SYSTEM	$ 84.50
#146 REMOTE TEMPERATURE SYSTEM	$ 150.00
#218 REMOTE HUMIDITY SYSTEM	$ 150.00
#975 COMPLETE SET OF FIVE DIALS	$ 475.00

SCIENCE ASSOCIATES, Inc.
P. O. Box 216 194 Nassau Street Princeton, N. J.
Write for complete catalog of weather instruments and teaching aids.

OPTICS

Special Coated Objectives

BIG 2⅛" DIAM. — 40" F.L. — $6.00

These tested achromatic lenses are the same high quality as our "Big Lenses," except for being seconds because of slight edge chips or small scratches.

Cat. No. S1804 ..... **Only $6.00 ppd.**

Mounted Eyepieces

The buy of a lifetime at a great saving. First choice of the amateur and professional astronomer. Perfect lenses set in black anodized standard 1¼" O.D. aluminum mounts.

Cat. No.	F.L.	Type	ppd.
S2192	6 mm. (¼")	Orthoscopic	$13.25
S1851	6 mm. (¼")	Ramsden	4.75
S1853	12.5 mm. (½")	Ramsden	4.50
S1207	12.5 mm. (½")	Symmetrical	6.00
S1251	16 mm. (⅝")	Erfle (wide-angle)	12.50
S1257	16 mm. (⅝")	Orthoscopic	12.50
S1209	18 mm. (¾")	Symmetrical	6.00
S1211	22 mm. (27/32")	Kellner	6.00
S1835	27 mm. (1-1/16")	Kellner	4.50
S1355	32 mm. (1¼")	Plossl	12.50
S1253	35 mm. (1⅜")	Symmetrical	8.00
S1255	55 mm. (2-3/16")	Kellner	6.00
S1485	56 mm. (2¼")	Symmetrical	6.00

COATED LENSES 75 cents extra.

"Giant" Wide-Angle Eyepiece

COATED LENSES 75 cents extra.

Erfle eyepiece best for low-power performance. Superior six-element design. 65° field, 1½" E.F.L., clear aperture 2⅛", focusing mount and diopter scale. Combine this eyepiece with our 5" objective No. S1475 for a tremendous light-gathering Rich-Field Telescope.

Cat. No. S1405 (illustrated) ..... **$12.50 ppd.**
Cat. No. S1858 Same as above without diopter scale ..... **9.95 ppd.**

● **FREE RUBBER EYESHIELD** ● with S1405

Cat. No. S1594 1¼"-diam. ADAPTER for eyepiece above ..... **$3.95 ppd.**

ADAPTER PLATE AND TUBE. Aluminum tapered tube and adapter plate, black anodized and finished in black crackle. Slides into our 5" O.D. Aluminum Tubing No. S1511. These parts are used with the eyepieces above to make a Rich-Field Telescope. Details in our catalog.

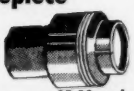
Cat. No. S2300 ..... **$18.00**

Wide-Angle Erfle

Brand-new eyepiece with 68° field; coated. E.F.L. 1¼". Focusing mount, 3 perfect achromats, 1-13/16" aperture.

Cat. No. S1020 ..... **$13.50 ppd.**
Cat. No. S1593 1¼"-diam. ADAPTER for eyepiece above ..... **3.95 ppd.**

An Economical Eyepiece



This mounted eyepiece has two magnesium-fluoride-coated achromatic lenses 29 mm. in diameter. Excellent definition. E.F.L. 1¼". Cell fits 1¼" tubing.

Cat. No. S1911 Coated ..... **$5.90 ppd.**
Cat. No. S1991 Not Coated ..... **5.25 ppd.**

Rack-&-Pinion Eyepiece Mounts

Here is a wonderful opportunity for you to own a most mechanically perfect Rack-&-Pinion Focusing Eyepiece Mount with variable tension and adjustment. Will accommodate a standard 1¼" eyepiece, positive or negative. The body casting is made of lightweight aluminum with black-crackle paint finish, focusing tube of chrome-plated brass. Focusing tube for refractors has a travel of 4", for reflectors 2". S1976 will fit all size tubing.

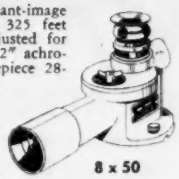
REFRACTOR TYPE

Cat. No. S1494 for 2⅛" I.D. Tubing ..... **$12.95 ppd.**
Cat. No. S1495 for 3¼" I.D. Tubing ..... **12.95 ppd.**
Cat. No. S1496 for 4⅜" I.D. Tubing ..... **12.95 ppd.**

REFLECTOR TYPE

Cat. No. S1976 (less diagonal holder) ..... **$8.50 ppd.**
Cat. No. S1982 DIAGONAL HOLDER ..... **1.00 ppd.**

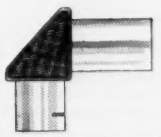
8-Power Elbow Telescope



This telescope has a brilliant-image 48° apparent field; actually 325 feet at 1,000 yards. Can be adjusted for focusing 15 feet to infinity. 2" achromatic objective, focusing eyepiece 28-mm. f.l., Amici erecting system. Turret-mounted filters: clear, red, amber, and neutral. Lamp housing to illuminate reticle for night use. Truly the biggest bargain you were ever offered. Original Gov't. cost $200.

Cat. No. S1686 Not Coated ..... **$13.50 ppd.**
Cat. No. S1975 Coated ..... **17.50 ppd.**

Star Diagonals



Guaranteed to make viewing the heavens with a refractor telescope 100% easier for the observer. Stop needless crouching forever. Choose the STAR DIAGONAL that best suits your requirements. Slides into standard 1¼" eyepiece mounts. Chromium tubes and aluminum housing, attractive black-crackle finish.

AMICI STAR DIAGONAL WITH ERECT IMAGE

For comfortable viewing of terrestrial or astronomical objects. The Amici prism gives an erect image.

Cat. No. S2095 ..... **$12.00 ppd.**

RIGHT-ANGLE PRISM STAR DIAGONAL

Contains a high-quality aluminized right-angle prism, wide field. Practical for astronomical use.

Cat. No. S2096 ..... **$12.00 ppd.**

MIRROR STAR DIAGONAL

Diagonal houses an excellent first-surface mirror, flat to within ¼ wave. Important accessory for refractor telescopes.

Cat. No. S2097 ..... **$12.00 ppd.**

7 x 30 Wide-Field Finderscope

Newly designed wide-field finderscope for reflector or refractor. Featured in this handsomely conceived black anodized aluminum tube are a 30-mm. coated achromatic objective, a wide-field Kellner eyepiece, and the all-important true crossline reticle for fast, exact locating. Compact and lightweight, 9" long, 1½" diam., 9 oz. May also be used as a hand-held telescope, offering excellent extra-wide-field views of the sky.

Cat. No. S2193 ..... **$9.75 ppd.**

Finder Ring Mounts

Made of cast aluminum with black crackle finish. Each ring has three locking wing screws for adjusting. Base has two holes for mounting screws, and fits any diameter tubing. Easy to attach. Ring mount No. S1963 will accommodate finder above.

Cat. No. S1963 .. 1-15/16" I.D. .. **Per Pair, $3.95 ppd.**
Cat. No. S1964 .. 2-11/16" I.D. .. **Per Pair, 3.95 ppd.**

New Prismatic Telescope

Coated **80-mm. Objective**

Big 80-mm.-diam. (3⅛") objective, for spotting or astronomical use. Will show stars of the 11th magnitude — 100 times fainter than the faintest visible to the naked eye. Table-top tripod included, extended 18", closed 13¾". Length of scope 16¼". Combined weight of scope and tripod is 5¼ lbs. All coated optics.

FIVE EYEPIECES

Power	Field at 1,000 yards	Exit pupil diam.	Relative brightness
15x	122 ft.	5.4 mm.	29
20	81	4.0	16
30	61	2.7	7
40	49	2.0	4
60	32	1.3	1

Cat. No. S2052 ..... **$59.50 ppd.**

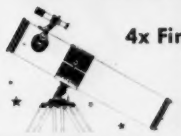
60-mm.-diam. Scope. Same as above but with smaller objective. Equipped with same five eyepieces — 15x, 20x, 30x, 40x, 60x. Coated. With tripod.

Cat. No. S1721 ..... **$42.95 ppd.**

4" Reflector Telescope

45x-225x

4x Finder — Wood Tripod



Study the sun and its spots. Observe galaxies, clusters, nebulae, and the Milky Way. Enjoy the thrill of being able to pick out small craters on the moon and see detail in the larger craters. A beautiful lunar landscape is brought to your doorstep. Bring distant events close to you; witness nature in action — eclipses, heavenly objects, and orbiting satellites. A high-quality telescope with an f/9 mirror. It has three eyepieces, 4-mm. (225x), 6-mm. (150x), 20-mm. (45x), and a free Barlow lens which will double the power. This will give 90x with the 20-mm. eyepiece, and 300x with the 6-mm. if observing conditions permit. Equipment tray keeps eyepieces clean and at hand. Sun and moon filters are included. Collapsible wood tripod makes scope portable, gives it stability and compactness. Finished in gray enamel with black trim. Imported. Shipping weight about 20 lbs.

FREE BARLOW LENS PLUS FREE BOOK "DISCOVER THE STARS" come with scope.

Cat. No. S2273 ..... **f.o.b. Lynbrook, N. Y., $59.50**

COATED BINOCULARS

Beautifully styled imported binoculars. Precision made.

LOW, LOW PRICES!

American Type

"Zeiss" Type

Complete with carrying case and straps. American type offers a superior one-piece frame and clean design. Individual Focus (IF) or Center Focus (CF).

Cat. No.	Size	Field at 1,000 yards	Type	Price, ppd.
S1149	6 x 15 IF	360 ft.	Opera	$12.75
S1436	6 x 30 CF	395	"Zeiss"	18.75
S1435	6 x 30 IF	395	"Zeiss"	16.75
S1438	7 x 35 CF	341	"Zeiss"	20.75
S1437	7 x 35 IF	341	"Zeiss"	17.95
S1771	7 x 35 CF	341	American	23.50
S1439	7 x 35 CF	578	American*	35.00
S2191	7 x 50 CF	530	American**	42.50
S1106	7 x 50 CF	372	"Zeiss"	24.95
S–961	7 x 50 IF	372	"Zeiss"	22.50
S1503	7 x 50 CF	372	American	32.50
S1443	8 x 30 CF	393	"Zeiss"	21.00
S1229	8 x 30 IF	393	"Zeiss"	18.25
S1108	10 x 50 IF	275	"Zeiss"	26.75
S1442	20 x 50 CF	183	"Zeiss"	33.75

*Wide-angle 11° **Wide-angle

Add 10% Federal tax to all prices above.

Monoculars

Brand new, coated optics, complete with pigskin case and neck straps.

Cat. No. S1576 ..... 6 x 30 ..... **$10.00 ppd.**
Cat. No. S1577 ..... 8 x 30 ..... **11.25 ppd.**
Cat. No. S1578 ..... 7 x 35 ..... **12.50 ppd.**
Cat. No. S1303 ..... 7 x 50 ..... **14.75 ppd.**
Cat. No. S1579 ..... 16 x 50 ..... **17.50 ppd.**
Cat. No. S1580 ..... 20 x 50 ..... **20.00 ppd.**

New! Zoom Binoculars

Six different powers at your fingertips in the same binocular: 7x, 8x, 9x, 10x, 11x, and 12x. Positive fingertip control accomplished by rotation of eyecups. Popular Center Focus, American type, 40-mm. objectives, all coated optics. Complete with carrying case and straps. **Add 10% Federal tax.**

Cat. No. S2303 ..... **$39.75 ppd.**

● **FREE CATALOG** ●

Millions of lenses, prisms, eyepieces, rack-and-pinion eyepiece mounts, cells, aluminum tubing, mirrors, binoculars, telescopes, parts, accessories, and so forth. Write today!

We pay POSTAGE IN U. S. — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded in 30 days.

A. JAEGERS

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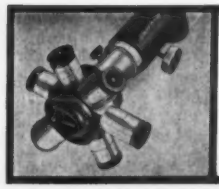


UNITRON
MONTHLY REPORT TO OBSERVERS

SEE THE BACK COVER FOR MORE NEWS ABOUT *UNITRON*

constellation of the month

CASSIOPEIA

On a crisp, dark November evening, Cassiopeia is the show constellation of the northern sky. To the naked-eye watcher of the heavens, its easily recognized W of five bright stars is an old friend. On rare occasions, this familiar appearance has been greatly changed. In the year 1572 a supernova flashed out in the constellation, becoming for a time as brilliant as Venus, and visible even in broad daylight. Again, in 1936 Gamma Cassiopeiae — the middle star of the W — unexpectedly doubled in brightness for several months.

Lying in the Milky Way, Cassiopeia is rich in fainter stars, inviting exploration with binoculars and view finders. It is even more rewarding to sweep slowly through this constellation with a UNITRON and low-power eyepiece, to see the black sky scattered with numberless glittering points of light, and here and there a brilliant gem.

Several of Cassiopeia's open star clusters are readily observable with your 3" UNITRON. For example, there is the rich stellar grouping in the field of Phi Cassiopeiae. Two of the clusters in Messier's historic list, M52 and M103, are in this constellation, and can be easily located with the aid of a star atlas such as Norton's or the Skalnate Pleso.

UNITRON users with a taste for double stars will want to view the famous binary Eta Cassiopeiae, a star pair of magnitudes 4 and 7, now separated by 10 seconds of arc. And a 3" UNITRON should readily split the three-second pair Sigma Cassiopeiae, a 5th-magnitude star with a 7th-magnitude companion.

Two handsome triple stars in this constellation are worthy of attention in 4" to 6" UNITRONS. First, Iota, of magnitude 5, has two companions, magnitudes 7 and 8, forming a compact triangle. Look also at Psi Cassiopeiae, a 5th-magnitude star accompanied at a distance of 25 seconds by a close pair of 10th-magnitude components.

24, XXIV, TWENTY-FOUR UNITRON MODELS TO CHOOSE FROM!

Now that all UNITRON Equatorials are available with Synchronous Motor Clock Drives, the prospective buyer has an even greater number of models from which to choose. In fact, unless we are mistaken, UNITRON now offers a wider selection than at any time in the history of the refractor.

All models come complete with mounting, tripod or pier, eyepieces, Achromatic Amplifier, accessories, and cabinets. While additional eyepieces and accessories are available for most models, the assortments included as standard equipment will be found remarkably complete.

2" SATELLITE (**$7.50 Down**) 6x, diagonal eyepiece, altazimuth mount with circles, stand — **$75**

1.6" ALTAZIMUTH, Model 127 (**$7.50 Down**) with eyepieces for 78x, 56x, 39x — **$75**

2.4" ALTAZIMUTH, Model 114 (**$12.50 Down**) with eyepieces for 100x, 72x, 50x, 35x — **$125**

2.4" EQUATORIAL, Model 128 (**$22.50 Down**) with eyepieces for 129x, 100x, 72x, 50x, 35x — **$225**

2.4" EQUATORIAL, Model 128C (**$27.50 Down**) same as Model 128 but with motor drive also — **$275**

3" ALTAZIMUTH, Model 140 (**$26.50 Down**) with eyepieces for 171x, 131x, 96x, 67x, 48x — **$265**

3" EQUATORIAL, Model 142 (**$43.50 Down**) with eyepieces for 200x, 131x, 96x, 67x, 48x — **$435**

3" EQUATORIAL, Model 142C (**$49.50 Down**) same as Model 142 but with motor drive also — **$495**

3" PHOTO-EQUATORIAL, Model 145 (**$55.00 Down**) with guide telescope, etc., and 6 eyepieces — **$550**

3" PHOTO-EQUATORIAL, Model 145C (**$61.00 Down**) same as Model 145 but with motor drive also — **$610**

4" ALTAZIMUTH, Model 150 (**$46.50 Down**) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x — **$465**

4" EQUATORIAL, Model 152 (**$78.50 Down**) with eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x — **$785**

4" EQUATORIAL, Model 152C (**$84.50 Down**) same as Model 152 but with motor drive also — **$845**

4" PHOTO-EQUATORIAL, Model 155 (**$89.00 Down**) with guide telescope, etc., and 7 eyepieces — **$890**

4" PHOTO-EQUATORIAL, Model 155C (**$95.00 Down**) same as Model 155 but with motor drive also — **$950**

4" EQUATORIAL, Model 160V (**$98.50 Down**) with weight-driven clock drive, etc., and 7 eyepieces — **$985**

4" PHOTO-EQUATORIAL, Model 160 (**$117.50 Down**) same as Model 160 but with guide telescope, astro-camera, etc., and 8 eyepieces — **$1175**

4" EQUATORIAL, Model 166V (**$107.50 Down**) with weight-driven clock drive, metal pier, etc., and 7 eyepieces — **$1075**

4" PHOTO-EQUATORIAL, Model 166 (**$128.00 Down**) same as Model 166V but with guide telescope, astro-camera, Super-UNIHEX, etc., and 10 eyepieces — **$1280**

5" PHOTO-EQUATORIAL, Model 510, with clock drive, guide telescope, astro-camera, etc., and 10 eyepieces — **$2275**

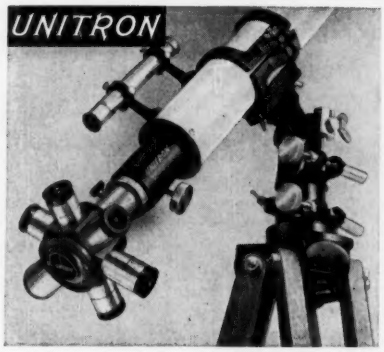
5" PHOTO-EQUATORIAL, Model 530, same as Model 510 but with metal pier instead of tripod — **$2385**

6" EQUATORIAL, Model 600, with clock drive, metal pier, etc., and 10 eyepieces — **$5125**

6" PHOTO-EQUATORIAL, Model 610, same as Model 600 but with guide telescope, astro-camera, etc. — **$5660**

6" PHOTO-EQUATORIAL, Model 620, same as Model 610 but with 80-mm. astrographic camera also — **$6075**

(Special payment plan available for 5" and 6" Models.)



UNITRON of every month

2.4" ALTAZIMUTH REFRACTOR

Here is America's most popular low-priced refractor.

The UNITRON 2.4" Altazimuth Refractor is not only a favorite with the beginning amateur, but is chosen by many owners of larger instruments as a second telescope because of its light weight and extreme portability. The best news about America's most popular refractor, though, is the low, low price. For only $125 you can treat yourself to an instrument which, optically speaking, duplicates the performance of larger telescopes of other makes. Complete with tripod, sturdy mounting, micrometric slow-motion controls, UNIHEX Rotary Eyepiece Selector, four eyepieces, sunglass, carrying case, and the new Achromatic Amplifier, this UNITRON can be yours for a mere 10% down payment of $12.50, using our Easy Payment Plan.

Investigate. See for yourself why more people are looking to the stars through a UNITRON than ever before.

HOW TO ORDER A UNITRON

Send check or money order in full or use our Easy Payment Plan. Shipments made express collect. Send 20% deposit for C.O.D. shipment. UNITRON instruments are fully guaranteed for quality, workmanship, and performance, and must meet with your approval or your money back. Prices of UNITRON Refractors include basic accessories, eyepieces, tripod and mounting, fitted cabinets, and instructions.

USE OUR EASY PAYMENT PLAN

UNITRON's popular Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor. The down payment required is 10%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is cancelled.

There is no "red tape" when you order — you merely fill in the UNITRON Easy Payment Order Form, return it together with the required down payment, and the model of your choice is shipped to you at once.

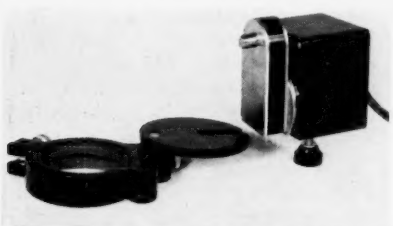
Do not hesitate to use this plan merely because you have never before purchased anything on time payments. The procedure is practically painless and is an ideal means of enjoying the use of your UNITRON while paying for it.

Does Santa know you want a UNITRON for Xmas?

Every year, Santa plans on a special sleigh to take care of the many UNITRON Refractors and accessories delivered at Christmastime. This year, with the new UNITRON models and motor drives to cope with, he will have even tougher sledding than ever before. Precision craftsmanship cannot be hurried and the number of UNITRONS available is necessarily limited. To avoid disappointment, *now* is definitely the time to reserve a UNITRON for that very special person on your Christmas list, who could be none other than yourself. Full payment or the down payment may be made at the time you wish to have the equipment delivered.

NEW UNITRON CLOCK DRIVES

As announced last month, Synchronous Motor Clock Drives are now available for all UNITRON Equatorial Models. The drive is designed so that it may be readily added to the many UNITRONS now in use without the need for any special adaptation.



The motor with gear box and shelf.

The rugged synchronous motor is mounted in an attractive metal housing to which is attached a compact reduction-gear assembly. A thumbscrew locks the housing to a small shelf which, in turn, clamps to the base of the equatorial mount, above the tripod head. The output shaft of the gear system connects directly to the right ascension hand drive knob. This method of coupling, using as it does the regular worm gear mechanism of the telescope, insures stability of the tube and eliminates the "play" that is often found in drives that connect directly to the polar axis. It takes but a minute to attach the drive, or to remove it for terrestrial observation or when you are viewing outdoors, away from a 110-volt outlet.

The resulting convenient arrangement is as shown in our back-cover advertisement in this issue. Recent UNITRON Equatorials have a right ascension knob drilled to accept the flexible-cable slow motion and the same hole is used as the connector to the gear box. For earlier models, a replacement control knob of the newer type will be supplied with the drive at no additional charge.

The prices for the motor drive are remarkably low for precision mechanisms of this type.

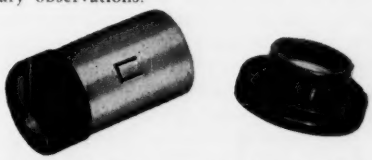
For 2.4" MODEL	**$50.00**
For 3" MODEL	**$60.00**
For 4" MODEL	**$60.00**

These prices are postpaid and include the complete assembly: motor, gear box, and special shelf.

If you are not already a UNITRON owner, you will want to refer to the listing on the page to your left and note the many clock-drive models which are now available. If you already have a UNITRON Equatorial, what better occasion is there than Christmas to bring your telescope up to date with one of these new drives? Since only a limited number of motor drives will be available for shipment before Christmas, it is not too early to order or reserve yours now.

A's FOR THE A.A.

In words of admiration and approbation, of acclamation and appreciation, amateurs have approved UNITRON's Achromatic Amplifier. This two-element, Barlow-type, negative amplifying lens doubles the customary power of each UNITRON eyepiece, giving you high magnifications for lunar and planetary observations.

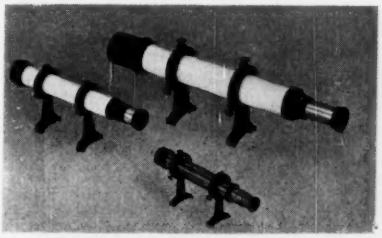


This useful and valuable accessory is included as standard equipment with all UNITRON Refractors at no extra cost.

If you purchased your UNITRON before the Achromatic Amplifier was available, you may obtain one at the special price of $6.00 — less than one third the price you'd pay elsewhere for an optical accessory of this quality. Two types of mounting cells are offered: one to fit the UNIHEX Rotary Eyepiece Selector and one for the UNITRON Star Diagonal. When ordering, be sure to state the type you require.

A VIEW FINDER REMINDER

Have you taken a critical look at and through your view finder lately? During an observing session, when not actually looking through your telescope, chances are your eye will be at the finder. All UNITRONS are equipped with quality finders of a size appropriate to each model. If you don't own a UNITRON, adding one of our precision view finders is an inexpensive way to modernize your present telescope and make observing more convenient. All models are supplied complete with brackets and collimating screws, as well as the screws needed to attach the finder to your tube.



1. **VIEW FINDER,** 23.5-mm. (.93"), 6x eyepiece. **Postpaid, only $8.50**
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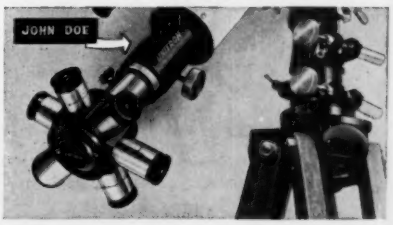

For some months now, we have been offering to ship your new UNITRON with a plastic name plate attached, as shown in the illustration above. It's really amazing just how many people named John Doe have responded. However, we should like to emphasize that we are capable of supplying other names as well. To get your UNITRON personalized, simply add this statement to your order: "Please attach a name plate to my telescope. This is the name: (print name clearly)." If you want, we can also add: XMAS 1961. There's no charge, of course.

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Eyepieces of Interest to Amateurs

MAGNIFICATION in a telescope is obtained by means of the ocular or eyepiece — a small microscope or magnifier that enlarges the image formed by the objective lens or primary mirror. This eyepiece ought to be of the best quality the observer can afford. For no matter how perfect the principal optics may be, the telescope's performance will be unsatisfactory if the eyepiece is inferior.

For many decades the best oculars for astronomical use have been *orthoscopic*. This term can refer to a type of design or, as is more common today, to a standard of performance. Originally and correctly, the term indicates the design of Ernst Abbe (1840-1905), a famous optical worker and theorist, founder of the Zeiss optical company.

It is only natural that orthoscopic performance has become a standard of comparison for oculars, which may be advertised as orthoscopic even though of other designs. As long as their performance is as satisfactory as a true orthoscopic, this practice should be acceptable. Some amateurs have taken commercial "orthoscopic" eyepieces apart, found them differing in design from the typical orthoscopic pictured in optics books, and have inquired of this department concerning the matter.

Therefore, the writer has checked many brands, enough to give a good cross section of the available oculars. Almost all of them have met the orthoscopic standard of performance, and are acceptable for astronomical work. The principal types of eyepieces available to American amateurs are shown in the chart on the facing page. If they are carefully designed and manufactured, their observing quality will be orthoscopic, with only a few exceptions that are noted below.

To a 1:1 scale, each diagram represents the proper size of a particular kind of eyepiece of 1-inch focal length. Radii of curvature, lens thickness, spacing, and distance from the telescope's focal plane (dashed line) have all been taken into account, and these factors can be roughly measured from the chart. Light passes through each system from left to right. The kinds of glass are indicated by hatching, which slopes downward to the right for crown, and upward to the right for flint.

In the following comments, *angular field* refers to the angle subtended at the eye by an object filling the field; on the average this is about 40°. In each case mention is made of the smallest focal ratio of the main telescope for which the eyepiece is suited. For focal lengths still shorter in proportion to aperture, the convergence of the light rays is too rapid for the eyepiece to accept them without introducing serious aberrations.

A. Orthoscopic. The basis of this design is a cemented triplet lens followed by a positive meniscus. Its angular field is 30°, and it gives excellent results on f/6 instruments. It is sometimes found with the single lens plano-convex, a design attributed to Mittenzwey. A third form, shown in the diagram, has the front element of the triplet with a plano surface and the single element is plano-convex. This is called a Hahn eyepiece.

To obtain a 40° field, in keeping with modern eyepiece needs, some manufacturers increase the size of the elements, but unfortunately this does not improve performance. The area of good definition remains 30°, and the design is degraded, as explained in *How To Make a Telescope*, by J. Texereau.

Before the advent of antireflection coatings for lenses, this eyepiece was bothered by strong ghost images, but coating of the elements reduces internal reflections to negligible amounts.

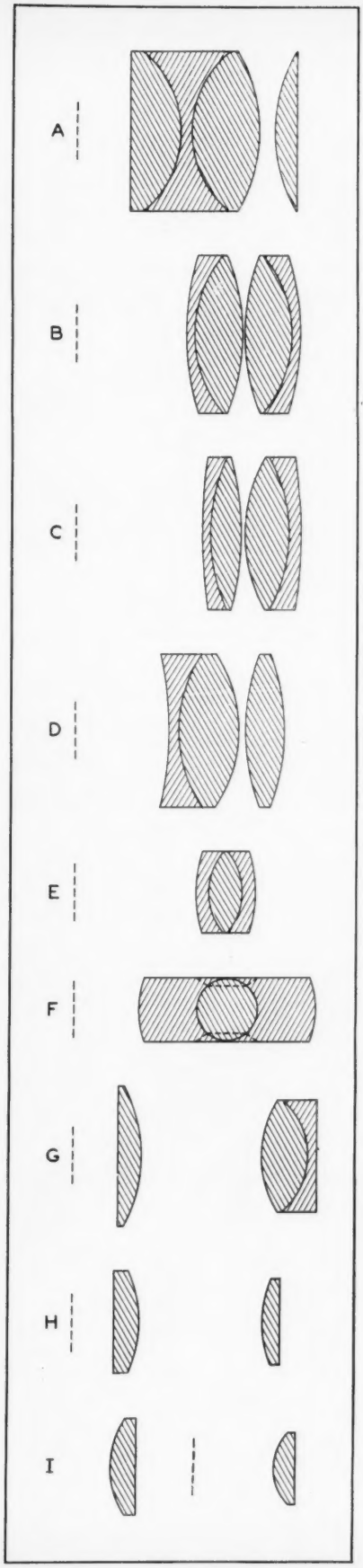
B. Symmetrical. Known under a variety of names including symmetrical, Steinheil, and Plössl, this eyepiece has a pair of achromatic lenses, usually identical in size, glass types, and construction. The crown elements face each other and are air-spaced a small distance apart. The first two named above are early models and have angular fields of 35° to 40° at f/6. The Plössl, using modern glass and design techniques, is a French ocular with a field of up to 50° at f/6. This is the eyepiece illustrated. Although they appear to be touching, the two lenses are separated at their centers by 1/500 inch.

It is possible with a pair of carefully chosen war-surplus achromatic lenses to construct a very passable, inexpensive form of symmetrical eyepiece of relatively long focus.

C. Abbe. Although it contains two achromatic lenses, the Abbe is not symmetrical. The front or field lens has a focal length $1\frac{1}{4}$ times that of the rear element. The air space is also greater than in the symmetrical ocular, but much smaller than in a Kellner eyepiece **(G)**. This is probably the eyepiece surplus houses offer as Kellners, but the lens spacing indicates a design nearer to the Abbe. The angular field is 40°, but use with faster telescopes than f/6 is not recommended.

D. Erfle. This popular item was originally made as shown here. Newer Erfles consist of an achromat for the field lens, another for the eye lens, and a simple double-convex element in between them. In this later form, the Erfle can cover a field of 60° with good definition at f/6.

The giant Erfle, used on Moonwatch and other amateur telescopes for excep-



tionally large fields of view, consists of three achromats. It is limited in its application to short-focus instruments only by strong astigmatism at the edges of the field, and will cover an apparent angle of 65° at f/6 with good results.

E. Triplet. This loupe or magnifier is a derivative of monocentric forms and is credited to Steinheil. It makes an excellent eyepiece, but its design must be aplanatic, that is, corrected for spherical aberration; otherwise, definition can be mediocre or poor. It has fine achromatism, a long working distance from the telescope's focal plane, and excellent eye relief. It operates at a focal ratio of f/6 with an angular field of 20° to 30°. There are a number of triplet lenses on the surplus market, but I have been unable to find one that performs well as an eyepiece.

F. Monocentric. Although not at present offered on the American market, this eyepiece has been included because of its high-quality images and performance. Its basic design is that of Steinheil, who used it in spectrometers and spectroscopes because of its excellent color correction. Many optical workers consider it a highly corrected form of solid eyepiece. It has three cemented lenses that are *monocentric*, all four surface radii having one common center at the middle of the assembly.

At focal ratios below f/6 the performance is not quite satisfactory. In actual construction the central ball is cut down, as shown by the dashed lines in the diagram. This reduces mass and internal reflections, and limits the field so that excessive curvature, beyond a 25° maximum angular field, does not detract from the otherwise fine images. The normal field of excellent definition is 16° to 20°, the ocular's only drawback.

Thus, after one has worked with a standard eyepiece or a wide-field Erfle, using a monocentric gives the impression of looking through a tunnel or tube. Yet, for lunar and planetary observing, on an equatorially mounted telescope with a good slow-motion or clock drive, this eyepiece performs splendidly. It was widely used by astronomers in the late 1880's and is still found extensively in Europe today.

G. Kellner. In the original design, the field lens of this eyepiece was double convex, but today it is usually plano-convex, as drawn. This is the old achromatic Ramsden. It has an apparent field of 30° to 40° at f/6, but extending it beyond this limit will give poor edge definition just as in the orthoscopic.

H. Ramsden. This and the Huygens (I) ocular are simple, efficient, and inexpensive. Their performance is not orthoscopic, but if properly designed and mounted they can give good results on small telescopes, Ramsdens for reflectors, Huygens for refractors.

Originally the Ramsden had both of its

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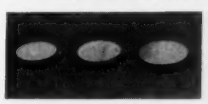

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5. **Kellner** — *30-mm. f.l., crosshair reticle with millimeter calibration marks. May be used as comparator* **$3.50**

6. **Kodak Aero-Ektar Lens** — *12" f.l., f/2.5, coated. With shutter, speeds of 1/25, 1/50, 1/100 second. This is the lens popularly used to photograph dim astronautical objects such as satellites* **$70.00**

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9. **AN/SSS1-1 Bendix Sextant** — *may be used as either artificial-horizon or bubble type. Contains spring-wound integrator. Complete with instructions and carrying case. Excellent condition* **$9.50**

10. **C-5 Lens Cone** — *coated Kodak 24"-f.l. f/6.0 lens mounted in Fairchild 3½" electrified Rapidyne shutter and servo- or manually operated diaphragm. This is a component of the current KA-2 aircraft reconnaissance camera, and represents the state of the art in shutter development. Excellent condition in fiberglass carrying case, with manual of operating and service instructions* **$95.00**

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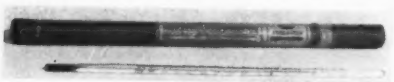

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18. **6"-f.l. f/4.5 Bell & Howell Eyemax Telephoto** — *intended for 35-mm. frame on gun cameras. Fixed focus mount, yellow filter. New* **$16.00**

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plano-convex elements of the same focal length and size. However, better performance results if the field lens is of slightly longer focus than the eye lens, as shown in our diagram. Although the lenses are similar to those of the Huygens, turning their plano surfaces outward places the focal plane in front of the ocular, as with all the eyepieces mentioned earlier. The Ramsden is, therefore, a *positive* ocular. Its spherical aberration is roughly one eighth that of the Huygens, and it performs well at focal ratios of f/8, even down to f/6 without serious harm. The angular field is between 30° and 40°.

Designed for relatively steep cone angles, however, the simple Ramsden is not as suitable for long-focus reflectors or refractors as are the orthoscopic-quality oculars already described. In fact, it is inferior to the Huygens arrangement in such cases.

I. Huygens. The convex surfaces of the lenses face the incoming light, and the focal plane lies between them. Since this design cannot be used for a simple magnifier, it is a *negative* eyepiece. In the case illustrated, the front lens has 1.6 times the focal length of the rear one, the combination yielding a field of about 30°.

The Huygens is used on low-cost refractors or compound telescopes where the long, narrow cone angle in the focal plane favors its performance. At less than f/10, spherical aberration becomes most serious, and a Huygens should never be used with short-focus instruments or the standard Newtonian reflector.

Our list by no means exhausts the varieties on the market today, but it does represent the major types and indicates what to look for in selecting eyepieces for your telescope.

Recently I have tested a *zoom* eyepiece on a 12-inch reflector. With this revolutionary device, focus can first be obtained at a low power, then easily zoomed to a high power by the turning of a knurled barrel. The ocular tested varied in focal length from 21 mm. to 8.4 mm., giving a range of 2½ to one in magnification. Although the highest power needed a slight retouching of the rack and pinion, the image was clear and sharp. A focal length of 16 mm. was dialed and the definition and field were compared with a standard ocular of orthoscopic performance — it was difficult to decide if any difference existed between them.

If imported zoom eyepieces of this quality can be made generally available, many amateurs may wish to reconsider their eyepiece problem. Not only does a zoom ocular do away with a battery of eyepieces, but it makes any focal length or size of field available between wide extremes. The power can be chosen to fit the object under observation, and can be varied at will as seeing and other observing conditions change.

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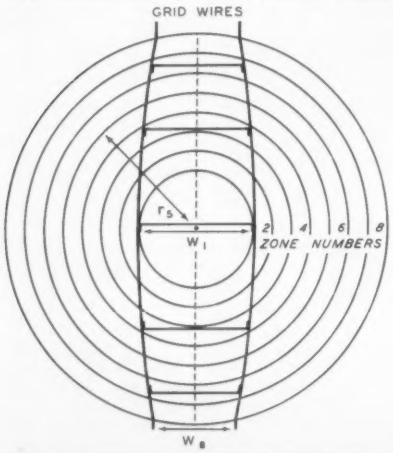
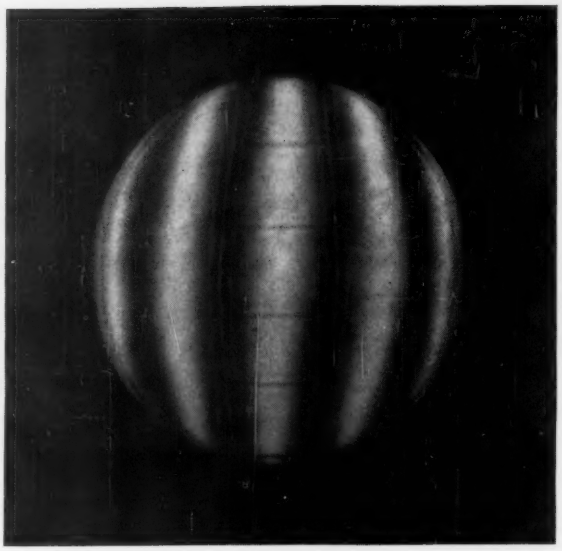
Figuring a Paraboloid with the Ronchi Test

RONCHI testing of a spherical surface – figuring the mirror until the silhouetted lines of a Ronchi grating appear straight and even – is used by many amateurs, especially for steep curves such as Maksutov lenses have. The method is difficult to use with parabolic mirrors, however, because their Ronchi bands are parabolas, and there is no obvious means for telling whether the mirror to be tested displays shadows that depart by a small amount from the ideal.

I have found that a way to overcome this difficulty is to make a wire grid formed to the curvature desired for the two central bands. The grid is placed over the mirror face and the figuring proceeds until the wires just bisect the shadows. Zonal measurements are not involved, discrepancies of figure being obvious at a glance. The grid can be used as a check on the results of Foucault testing, adding many of the advantages of the Ronchi test (*Amateur Telescope Making – Book I*, page 264, 4th edition).





In the author's photograph of his 10-inch mirror under the Ronchi test, the superimposed wire grid produces a pattern of fine white lines in the central shadow bands. Figuring is continued until the bands and fine lines are uniformly coincident along their length. At the left below is the layout (reduced) of the grid calculation for this mirror, which has a focal length of 62½ inches. The actual separation of the concentric circles is half an inch.

A template must first be made for the grid. Select a maximum width, w_1, between the central shadow bands. The larger their separation, the more sensitive the test, but the larger also will be the untested central area of the mirror. A good compromise is 25 to 30 per cent of the mirror's diameter.

Draw on paper a circle the full size of the mirror, with a convenient number of concentric circles inside it, beginning with radius $\frac{1}{2}w_1$ and proceeding outward. These will serve as zones for determining the grid's curvature.

The width, w, between the shadow bands at any zone is dependent on R, the radius of curvature of the mirror, on

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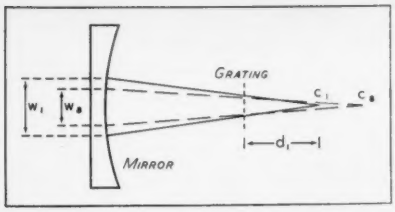

The test setup from above, showing light paths for the Ronchi band's central part (to c_1) and its intersection with the edge of the mirror (to c_8).

G, the number of wires per inch in the Ronchi grating, and on d, the distance the grating is placed inside the zone's center of curvature. This distance will increase from the inner to the outer zones in a parabolic mirror, because the actual radius of curvature is longer for the outer zones of the parabola.

We have, first of all, the following basic relation:

$$w = \frac{R}{Gd}, \qquad (1)$$

which may be rewritten as

$$d_1 = \frac{R}{Gw_1}, \qquad (2)$$

where d_1 applies to the radius of curvature of the mirror's central zone, and w_1 is the central band width, established arbitrarily as explained above. We can easily evaluate d_1, since all the quantities on the right side of equation (2) are known.

In general, however, the regular zonal calculation r^2/R gives us the value of the distance d for any zone between the grating (which remains fixed) and the center of curvature of the zone. The distance has differing values for different zones:

$$d = \frac{r^2}{R} - \frac{r_1^2}{R} + d_1, \qquad (3)$$

with r and r_1 the radii on the mirror of the zone in question and the first zone, respectively.

Equation (3) may be rewritten, substituting the value of d_1 from (2):

$$d = \frac{r^2 - r_1^2}{R} + \frac{R}{Gw_1}. \qquad (4)$$

Finally, substituting this in the basic formula for w, given in (1) above, yields the expression

$$w = \frac{R^2 w_1}{R^2 + Gw_1(r^2 - r_1^2)}. \qquad (5)$$

In practice, computing by means of (5) is quite simple. Once w_1 has been decided upon, the numerator becomes constant, as do R^2 and Gw_1 in the denominator. The radius of the first zone, r_1, is, of course, half of w_1; r_2 is the radius of the second zone, and so on.

As an example, consider a 10-inch mirror with a radius of curvature $R = 125''$ (f/6.25), and a grating with $G = 100$ wires per inch. Taking w_1 as $3''$, $r_1 = 1\frac{1}{2}''$. Solving equation (2) determines that the grating will be set up 5/12 or $0.417''$ inside the center of curvature as determined by the knife-edge test.

RONCHI PATTERN FOR 10-INCH MIRROR

Zone	*Radius*	*Band Spacing*
1	1.5″	3.00″
2	2	2.90
3	2.5	2.79
4	3	2.66
5	3.5	2.52
6	4	2.37
7	4.5	2.23
8	5	2.09

Let the value of r_2 be $2''$, which substituted for r in (5) gives for w_2 the figure 2.9025. In this way, the above table of the widths between the innermost Ronchi bands at each of the intersections with the circular zone pattern can be set up. Using formulas (2) and (5), the reader should have little difficulty in setting up a similar table for a mirror of other specifications.

After obtaining a table, draw a central vertical line on the paper marked in zones. Lay off $\frac{1}{2}w$ for each zone on either side of the line, both above and below center, so that the circle of the appropriate zone is intersected at four points. Connect the points on each side of the line with smooth curves, and the centers of the inner Ronchi shadows will be drawn.

Tack this pattern onto wood, with nails on each side of the lines, and bend the grid wires, leaving them about $\frac{1}{2}''$ too long at each end, so that they can be hooked over the mirror. Solder spacers between the wires and hang the grid over the mirror by the bent wires. The grid must be exactly centered, which may require some adjusting.

When the shadow bands are seen inside the grid wires, the radius of curvature is too long and the curve too flat for that zone. If the bands fall outside the wires, the curve is too steep.

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ED. NOTE: The relationship between Ronchi band patterns and mirror figures has been fully discussed by A. A. Sherwood in the *Journal* of the British Astronomical Association for July, 1958, pages 180-190. He considers deep spherical and shallow aspheric surfaces.

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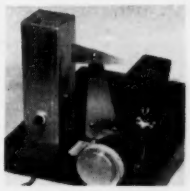

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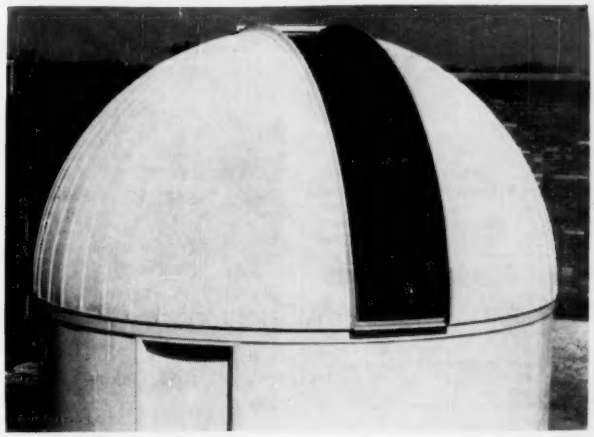

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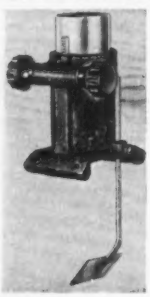

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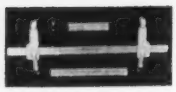

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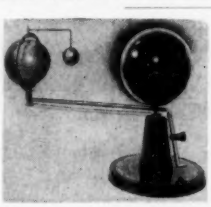

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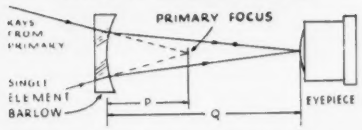

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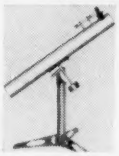

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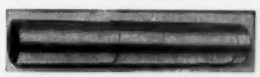

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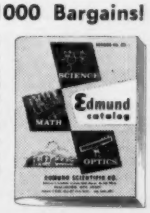

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SW Andromedae — A Cluster-Type Variable

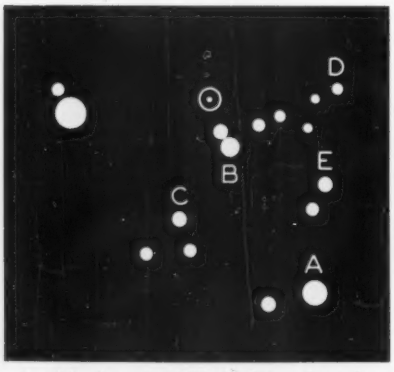
An attractive variable star for amateur observations with small telescopes, SW Andromedae is one of the brighter cluster-type variables, or RR Lyrae stars as they are more often called nowadays. These objects resemble Cepheid variables, but have periods of around half a day, instead of several days or weeks. SW Andromedae's period is 10.61 hours, and its approximate visual magnitude range is 9.3 to 10.3.

The 1950 co-ordinates of this star are $0^h\ 21^m.1$, $+29°\ 07'$. If your telescope does not have setting circles, a simple way to locate SW is to point the instrument at Alpha Andromedae, placing that star near the southern edge of the field of a low-power eyepiece. Then, leaving the telescope stationary, wait 15.3 minutes, and the star configuration in the accompanying chart will be visible.

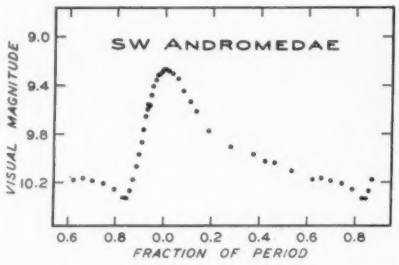
As the light curve shows, SW undergoes little change in brightness for about four hours, when near minimum. The most interesting time to watch is during the fast rise to maximum light, while the variable brightens by a magnitude in only $1\frac{3}{4}$ hours. Then the star begins to fade nearly as rapidly, but eventually at a slower rate. The following predictions are of maxima occurring during hours of darkness in the United States; they are expressed in hours and tenths of hours, Universal time:

November 1, $7^h.0$; 2, $4^h.2$; 3, $1^h.4$; 5, $6^h.5$; 6, $3^h.7$; 7, $0^h.9$; 9, $6^h.0$; 10, $3^h.2$; 11, $0^h.5$; 13, $5^h.5$; 14, $2^h.8$; 15, $0^h.0$; 16, $7^h.8$; 17, $5^h.1$; 18, $2^h.3$; 20, $7^h.4$; 21, $4^h.6$; 22, $1^h.8$; 24, $6^h.9$; 25, $4^h.1$; 26, $1^h.4$; 28, $6^h.4$; 29, $3^h.7$; 30, $0^h.9$.

To predict other maxima, add or subtract multiples of 10.61 hours from the listed times.



In this chart for SW Andromedae, the variable is circled. South is upward, east to the right, and the height of the chart is 40 minutes of arc. Visual magnitudes for the comparison stars are: A, 8.2; B, 8.8; C, 9.3; D, 10.2; and E, 11.2. Adapted from P. G. Kulikovsky, "Amateur Astronomer's Handbook," Moscow, 1961.



The visual mean light curve of SW Andromedae, from 550 photometric observations made by L. Detre at Budapest Observatory. Just before the variable starts its rapid rise to maximum light, there is a short dip in brightness — a feature common among cluster-type variables of similar period.

The variability of SW Andromedae was discovered in 1907 by Miss A. J. Cannon while studying Harvard Observatory sky patrol photographs. Since then, the star has attracted much attention. One reason is a variation in the shape of the light curve, requiring 37 days to run its course. This secondary oscillation is, however, so small that it is best studied with a photoelectric photometer.

Another, more striking effect is a progressive shortening of the star's period. Predictions made with a constant period will be a quarter of an hour late after the lapse of a decade. The latest formula for predicting times of maximum was derived in 1959 by the German astronomer P. Ahnert: $J.D.\ Max. = 2436504.427 + 0^d.442268E$, where E is the number of cycles elapsed since the initial epoch.

OCCULTATION OF ALDEBARAN AND REGULUS

Late this month two 1st-magnitude stars will be occulted by the moon, Alpha Tauri on November 22nd and Alpha Leonis on the 29th. Although the first event will be visible from most of North America, it will occur rather early in the evening; the occultation of Regulus will be seen from the South and Far West.

Glare from the moon, only a day past full, will make observation of the immersion of Aldebaran rather difficult. In Massachusetts, this is around 8:00 p.m. Eastern standard time on November 22nd. Reappearance is about one hour later. For Illinois the figures are 6:49 and 7:47 p.m. Central standard time. Predictions are not given for southern California, the moon being near the horizon, but observers in the Northwest will be able to view reappearance.

Regulus will disappear at the bright limb of a waning gibbous moon on the morning of November 29th. For Texas, immersion is at 6:25 a.m. CST, with emersion at 7:53, after sunup. In southern California the star will go nearly centrally behind the moon, disappearing at 3:30 a.m. Pacific standard time at position angle 104°, and reappearing from the dark side at 5:02, position angle 300°.

More exact times, and predictions for other locations in the United States and Canada, may be found in the Occultation Supplement, Sky and Telescope for December, 1960.

NOVEMBER METEORS

Observations of this month's two rather sparse meteor showers will not be seriously affected by the moon. Maximum of the Taurid shower on November 5th occurs three days before new moon; some Taurids may be seen two weeks before and after that date. The Leonids are at maximum on November 16th, at first-quarter moon, the radiant rising about midnight. At the peaks of both showers a single observer may see some 15 meteors per hour: about half belong to the shower, and the rest are sporadic.

WILLIAM H. GLENN

VARIABLE STAR MAXIMA

November 6, T Normae, 153654, 7.4; 10, R Ophiuchi, 170215, 7.9; 16, S Pegasi, 231508, 8.0; 17, U Herculis, 162119, 7.5; 18, RU Herculis, 160625, 8.0; 19, R Canis Minoris, 070310, 8.0; 28, U Octantis, 131283, 7.9.

December 2, T Cephei, 210868, 6.0; 2, R Cassiopeiae, 235350, 7.0; 3, S Ursae Majoris, 123961, 7.8; 4, R Normae, 152849, 7.2; 4, Chi Cygni, 194632, 5.2; 7, T Centauri, 133633, 5.5.

These predictions of variable star maxima are by the AAVSO. Stars are listed only if brighter than magnitude 8.0 at an average maximum. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the date given. The data include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted visual magnitude.

MINIMA OF ALGOL

November 3, 18:52; 6, 15:41; 9, 12:30; 12, 9:19; 15, 6:08; 18, 2:57; 20, 23:46; 23, 20:35; 26, 17:24; 29, 14:13.

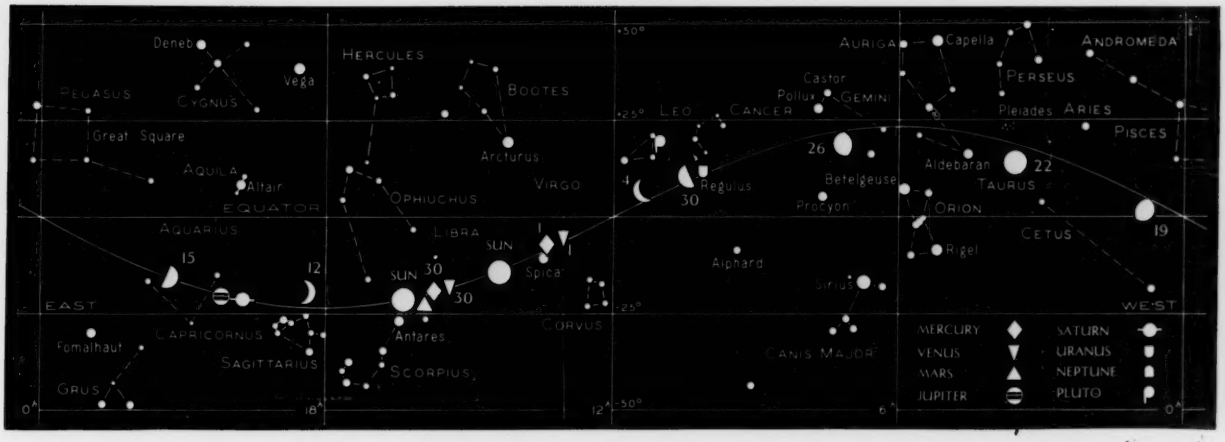
December 2, 11:02; 5, 7:51; 8, 4:41; 11, 1:30.

These minima predictions for Algol are based on a recent timing by D. Engelkemeir and an assumed period of 2.8674 days. The times given are geocentric; they can be compared directly with observed times of least brightness.

MOON PHASES AND DISTANCES

New moon	November 8,	9:59
First quarter	November 15,	12:13
Full moon	November 22,	9:44
Last quarter	November 30,	6:19
New moon	December 7,	23:52

November		Distance	Diameter
Apogee	2, 2^h	251,400 mi.	29′ 32″
Perigee	17, 5^h	229,700 mi.	32′ 20″
Apogee	29, 22^h	251,200 mi.	29′ 33″
December			
Perigee	12, 0^h	228,900 mi.	32′ 27″



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0h Universal time on the respective dates.

Mercury is an easy object to observe this month, for at greatest western elongation (19°) on the 7th it rises more than 1½ hours before the sun. During the first three weeks of November the planet may be readily seen low in the eastern sky. On the 7th its stellar magnitude will be −0.3, and through telescopes its 6″.9-diameter disk will appear half illuminated. Mercury is near Venus during much of this current apparition, and both planets will follow the thin crescent moon in the early morning sky on November 6th, as described on page 283.

Venus rises about 1½ hours before sunup during most of November, a very bright object (magnitude −3.4) low in the eastern morning sky. On the 15th, Venus will show telescopically an almost fully illuminated disk, 10″.5 in diameter.

Mars sets just after the sun and cannot be seen in the solar glare.

Jupiter, in Capricornus, transits around sunset. On the 15th it is of magnitude −1.8, and its telescopic disk is 34″.4 in polar and 36″.9 in equatorial diameter. The moon passes 3° north of Jupiter at 0h UT November 14th.

Saturn is in Sagittarius, leading Jupiter across the sky by an increasing amount, becoming 6° by midmonth. Then of magnitude +0.8, Saturn has a flattened telescopic disk 14″.3 in polar diameter. The north face of the rings is seen this year; on November 15th their plane will be inclined 22°.6 to our line of sight, the ring system's major axis being 36″.0.

Uranus may be found easily with binoculars, for the 6th-magnitude planet rises near local midnight and on the 15th is only about 1° east of Regulus, at right ascension 10h 10m.1, declination +12° 06′ (1950 co-ordinates). Two lunar occultations of Uranus occur this month, one on the 2nd, visible in South America and South Africa, the other on the 29th over the Pacific Ocean.

Neptune is too close to the sun to be observed, being in conjunction on November 3rd and passing into the morning sky.

WILLIAM H. GLENN

MINOR PLANET PREDICTIONS

Euphrosyne, 31, 10.3. November 7, 4:53.7 +46-11; 17, 4:43.3 +48-20; 27, 4:29.4 +50-04. December 7, 4:13.9 +51-13; 17, 3:58.9 +51-44; 27, 3:46.8 +51-44. Opposition on November 30th.

Euterpe, 27, 9.4. November 17, 5:33.3 +22-02; 27, 5:26.3 +22-06. December 7, 5:16.7 +22-08; 17, 5:06.2 +22-08; 27, 4:56.7 +22-09. January 6, 4:50.0 +22-11. Opposition on December 11th.

After the asteroid's name are its number and the approximate visual magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

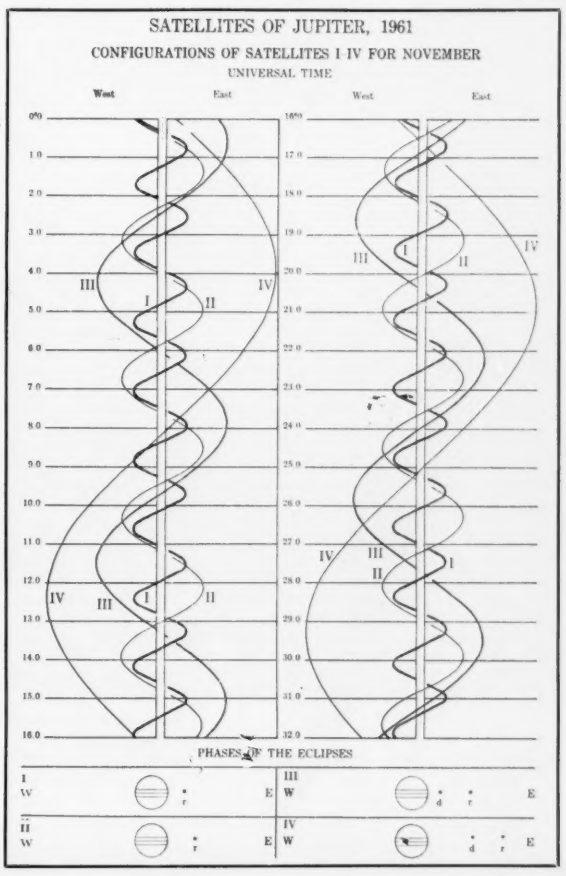
UNIVERSAL TIME (UT)

In the Celestial Calendar, Universal time (Greenwich civil time) is used unless otherwise specified. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown. For example, 6:15 UT on the 15th of the month corresponds to 1:15 a.m. EST on the 15th and to 10:15 p.m. PST on the 14th.

JUPITER'S SATELLITES

The four curving lines represent Jupiter's four bright (Galilean) satellites: I, Io; II, Europa; III, Ganymede; IV, Callisto. The location of the planet's disk is indicated by the pairs of vertical lines. When a satellite passes in front of Jupiter, its curve crosses the lines. If a moon is invisible because it is occulted by Jupiter or is in the planet's shadow, the curve is broken.

For successive dates, the horizontal lines mark 0h Universal time, or 7 p.m. Eastern standard time (4 p.m. Pacific standard time) on the preceding day. Along the vertical scale, 1/16 inch is about seven hours. In this chart, west is to the left, as in an inverting telescope for a Northern Hemisphere observer. At the bottom, "d" is the point of disappearance of a satellite in Jupiter's shadow; "r" is the point of reappearance. From the "American Ephemeris and Nautical Almanac."



OPTICS NEWS:

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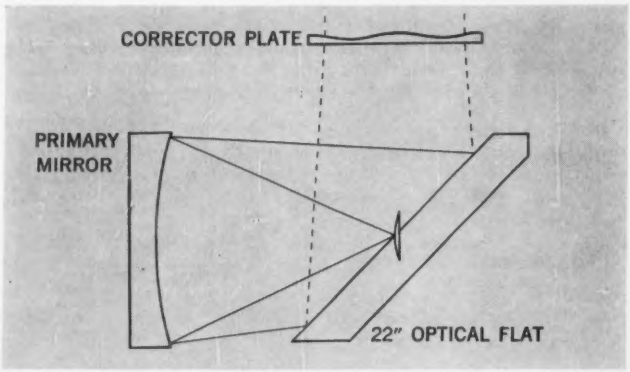
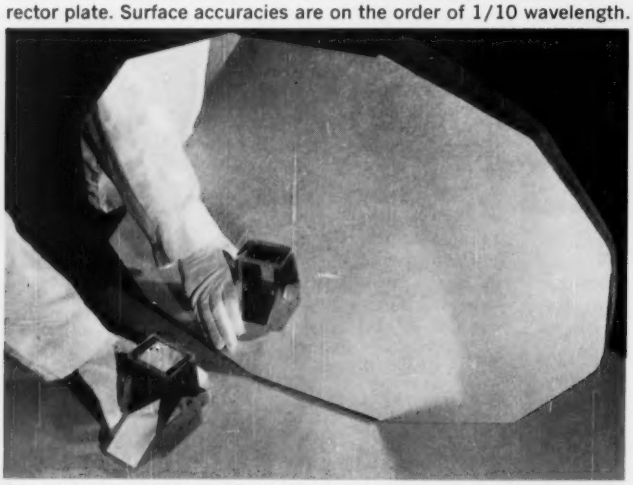


This Schmidt system is particularly unusual in that it is based on performance at fixed conjugates. The primary mirror is 16" in aperture and the spherical aberration it causes is corrected by the aspheric corrector plate. Surface accuracies are on the order of 1/10 wavelength.



These two fused-silica optical assemblies were made for Space Technology Laboratories Inc., to be used in the "Skyscraper" airborne instrumentation system. For weight-saving purposes, the larger assembly, whose major dimension is 32", has an unusual shape. The smaller assembly is a "K" mirror whose component parts are joined solely by optical contact. It performs the same function as a dove prism but differs in that it uses reflection rather than refraction. This method permits greater efficiency over the full spectral range.

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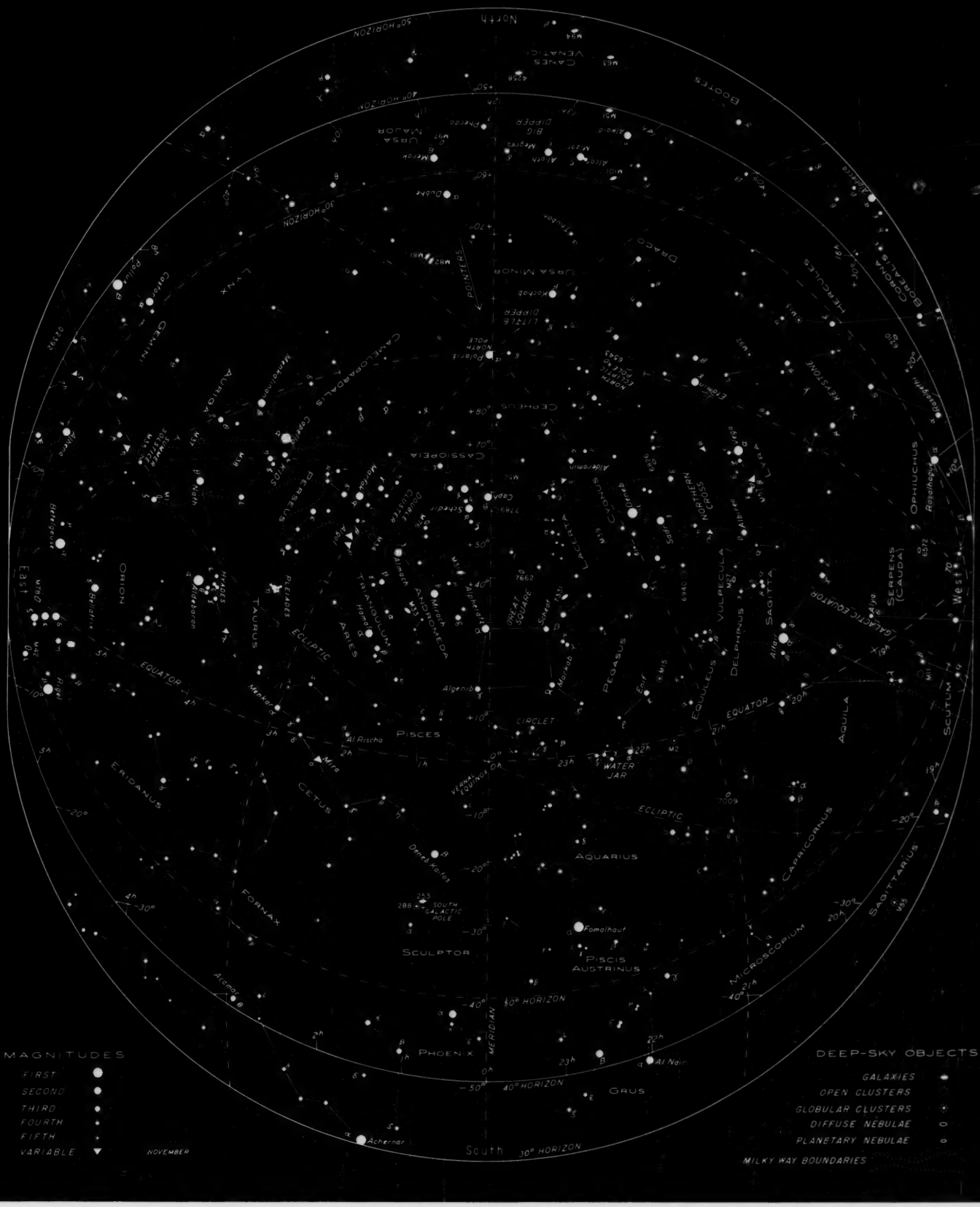

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STARS FOR NOVEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 6th and 21st of November, respectively; also at 7 p.m. and 6 p.m. on December 6th and 22nd. For other dates, add or subtract ½ hour per week.

On the meridian at chart time, about 2½ degrees northeast from the midpoint of a line joining Markab and Deneb Kaitos, lies the March equinox. Marking the zero of right ascension, this point is the location of the sun at the beginning of northern spring and southern fall.

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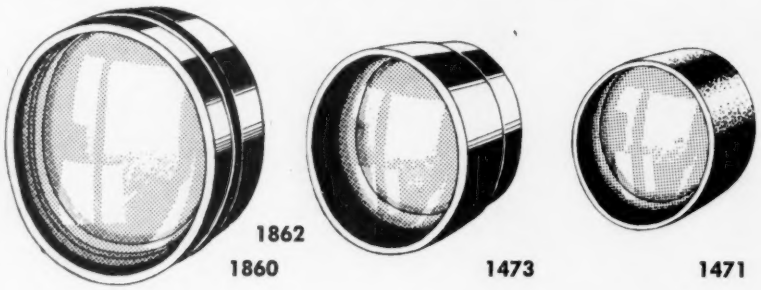

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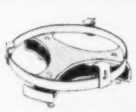

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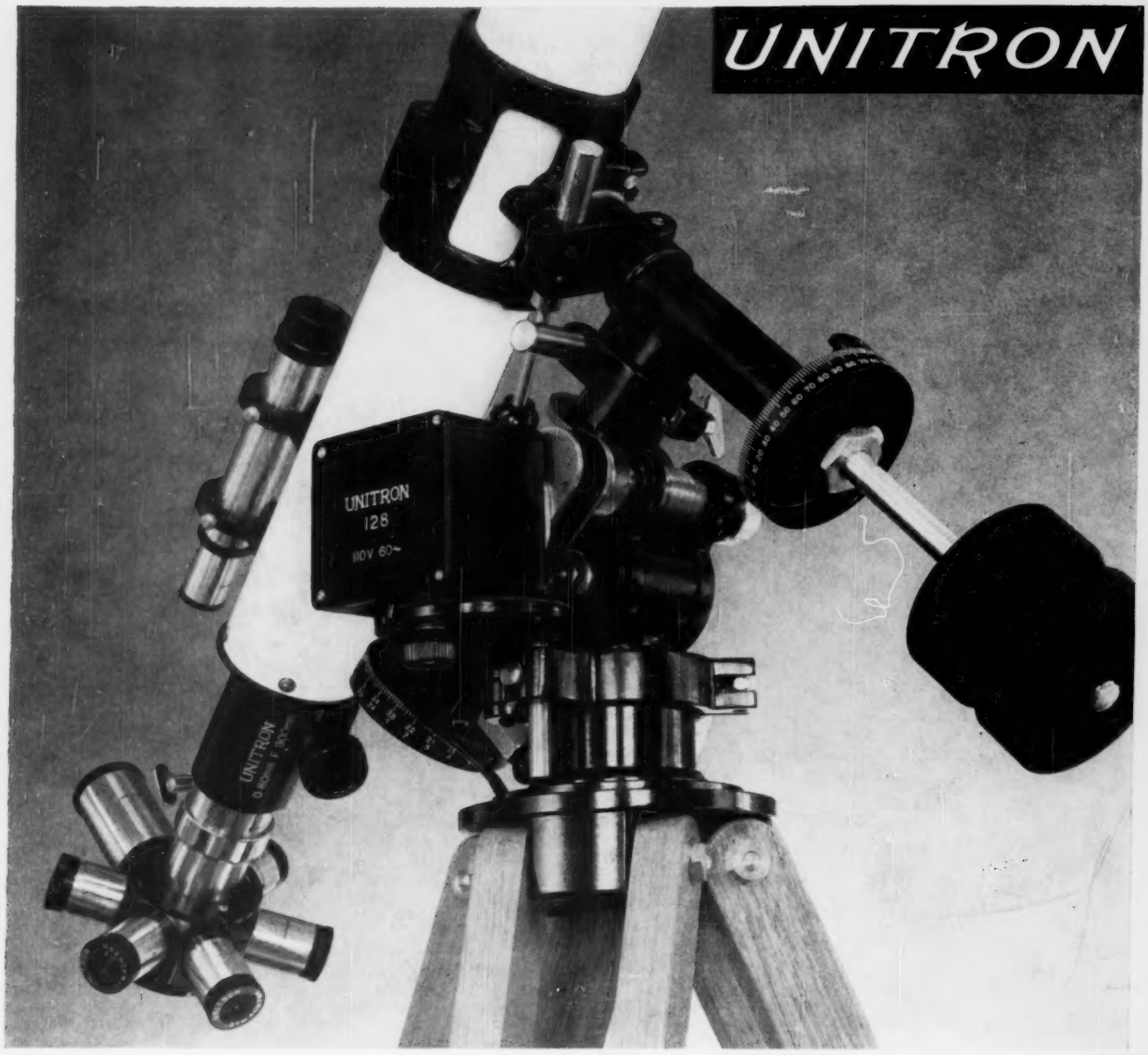

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See pages 292 and 293.

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